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LEFT VENTRICULAR AND SYSTEMIC ARTERIAL CATHETERIZATION: A SIMPLE PERCUTANEOUS METHOD USING A SPRING GUIDE*

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FOLLOWING a lead provided by Seldinger,[12] Prioton *et al.*[11] in 1957 described a technique for catheterization of the left ventricle via percutaneous femoral artery puncture and retrograde aortic passage of a special catheter through the aortic valve into the left ventricular cavity. This technique was soon employed by others with success[1,3,4,9,10] and has blazed a new, easily followed route for the study of lesions of the left side of the heart. It has proved to be of value in contrast visualization of aortic valvular lesions, mitral insufficiency, interventricular septal defect and coronary occlusion. It greatly simplifies thoracic aortography and is the method of choice for visualizing patent ductus arteriosus, aortic septal defect, coarctation and other lesions of the aorta. It is more selective, more reliable and less hazardous than ordinary translumbar aortography. It provides means for obtaining hemodynamic data and a route for the selective administration of drugs.

SPECIAL EQUIPMENT—THE SPRING GUIDE

Briefly, the procedure consists of introducing a needle into the femoral artery, and passing a long, flexible spring guide through the needle. The needle is immediately removed and polyethylene tubing is slipped along the guide into the artery. Guide and tubing are advanced until the desired position is achieved, whereupon the guide is withdrawn leaving the tubing in place to allow contrast or other injections, the removal of blood samples, or the determination of pressures (Fig. 1 and 2).

It is apparent that the two main features of this method are (1) the *percutaneous* route and (2) *simple, atraumatic retrograde passage through the aortic valve.* Both features are embodied in the special coilspring guide which is the *sine qua non* of the procedure. This guide, in effect a miniature "plumber's snake," consists of a long coilspring, tightly wound from stainless steel wire. A typical adult size spring guide is shown in Figure 1. In this case there are

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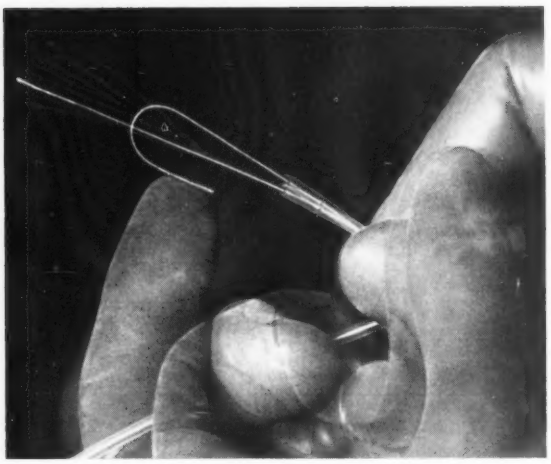

FIG. 1. *The Essentials—spring guide, polyethylene tubing and inner stainless steel wire stiffener* (hidden by guide; the latter extends about an inch beyond the end of the polyethylene tubing). Double exposure photograph shows flexibility and springiness essential to nontraumatic retrograde transvalvular catheterization.

115 turns per inch, wound to give an outer diameter of 1.2 mm. and an inner diameter of 0.7 mm. The exploring end is sealed off; the opposite or outer end accepts a somewhat longer No. 8 piano wire which may be advanced or withdrawn at will to vary the springiness of the guide tip. The illustrated guide calls for PE 205 or PE 240 polyethylene tubing; if the larger size is used, a slight taper is formed into the tip. The foregoing dimensions are satisfactory but certainly not critical. Table 1 lists the source, cost and description of a number of alternatives (as of January, 1960). Initial studies made use of French equipment available in kits consisting of the guide (3 sizes available), special needle and precut polyethylene tubing fitted with an adapter. Distance, time, cost, cleaning difficulties, wear and tear and donations to visiting colleagues made it desirable to secure a local source.

A music store provided a workable, though far from ideal, counterpart in fifth wound guitar strings. These are formed of somewhat coarser "music wire" (72 turns per inch) and are but 88 cm. in length. Though used successfully for the purpose, guitar strings are too short and too stiff for transvalvular catheterization. They are satisfactory for abdominal aortography. Ordinary guitar strings are supplied with a central wire core which must be removed (heat and patience help) and replaced with a No. 8 piano wire. The tips are readily sealed with solder. Satisfactory guides can be custom wound by spring manufacturers.

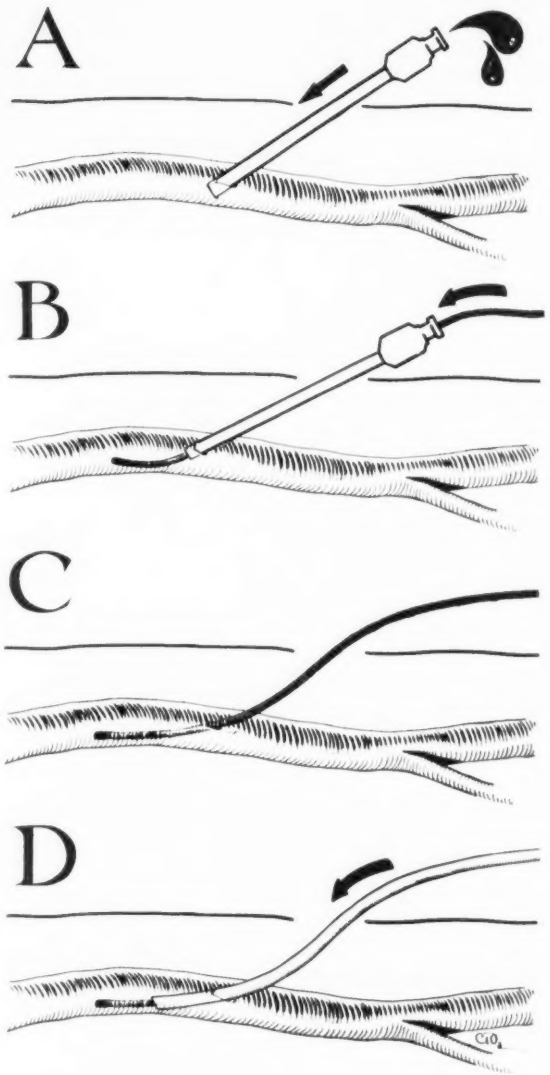

FIG. 2. *Percutaneous Arterial Catheterization.* (*A*) Needle is inserted into artery and inner stylus (if used) is withdrawn. (*B*) Spring guide is passed through needle and advanced a short distance within the arterial lumen. (*C*) Needle is withdrawn; guide remains in place. (*D*) Polyethylene tubing is advanced along the guide into arterial lumen. With fluoroscopy, guide and tubing are positioned as described and guide is withdrawn.

TABLE I

SPRING GUIDES: SOURCE OF SUPPLY

Source	Cost	Description				Stainless Steel Wire	Appropriate Size Tubing	Remarks
		Length (cm.)	Inner Diameter (mm.)	Outer Diameter (mm.)	Turns per Inch			
Syracuse Spring Corp. Erie Boulevard East Dewitt New York	$3.95 (in lots of 12)	120	0.78	1.17	115	0.37 0.41	PE 205 PE 240	Custom wound spring guide including stainless steel wire insert; tubing not included; both sizes used; end of the tubing may be reformed for snugger fit
Connor Spring Mfg. Co. 75 14th Street San Francisco 3, California	$2.72 (in lots of 25) $2.92	125 125	0.28 0.18	1.41 0.81	144 88	#8 #6	PE 240 PE 160	Custom wound springs (stiffening wire and tubing are not included)
Music Stores (guitar "A" string, fifth wound, Gibson brand)	$0.50	88	0.46	1.09	72	#8	PE 190	Stiff and somewhat short for use in adults; comes with central cores which must be removed; stiffening wire and tubing purchased separately
Bio-DuBernard, S. A. 3, Rue de Bearn 1, Rue du Foin Paris 3, France	$13.00 (per kit)	127 127 127	0.41 0.46 0.71	0.81 1.05 1.41	132 106 74	#6 #8 #8	PE 190 PE 190 PE 205	Sold in kits which include guide, tubing, and special needle; 3 available sizes
Shick X-Ray Co., Inc. 205 W. Wacker Drive Chicago 6, Illinois	$11.40	100	—	0.94	98	fixed	Special opaque	Odman-Ledin spring guide (and catheter); stiffening wire fixed in place at factory; not suitable for procedure as described

Thus far, high quality has not come to mean high cost as so often follows the discovery that a commonplace item has a medical application. As a consequence, guides are treated as expendable. While undamaged coilsprings can be reused, for the present at least, this is a false economy since it usually requires the replacement of bent piano wire stiffeners and always requires a meticulous, time-consuming cleaning. Inasmuch as the guide is metallic, the tubing need not be radiopaque, especially not if radiopacity were to be gained at the expense of optical transparency and/or thin walls. Clay-Adams' Intramedic tubing is economical, satisfactory for the purpose and available in an adequate variety of sizes appropriate to the guides used (Table 1). Before sterilization, a Luer-Lok adapter is attached to one end of a length of tubing about six inches shorter than the spring guide with which it is to be used. The end is cut on a bias of approximately 70° (to facilitate entry into the arterial lumen) and several side holes are punched in the terminal inch (to minimize recoil during injection). Longitudinal cracks in the cut end must be avoided since these will engage the vessel wall, thereby preventing introduction of the tubing.

Prior to use, the guide is inspected for defects and (with its piano wire stiffener in place) is inserted into the prepared length of the polyethylene tubing. The piano wire should be three inches longer than the guide and the guide six or more inches longer than the polyethylene tubing. The assembly comprising guide, stiffener and tubing is then sterilized and stored ready for heparinization at the time of the examination.

The remainder of the equipment necessary for the procedure consists only of an arterial needle which readily admits the guide (*not* the polyethylene tubing). A special needle equipped with a pointed, solid inner stylus and a stabilizing shield near its hub can be obtained but is not essential. Also used in the procedure are sterile syringes and such surgical accessories as might be employed in other forms

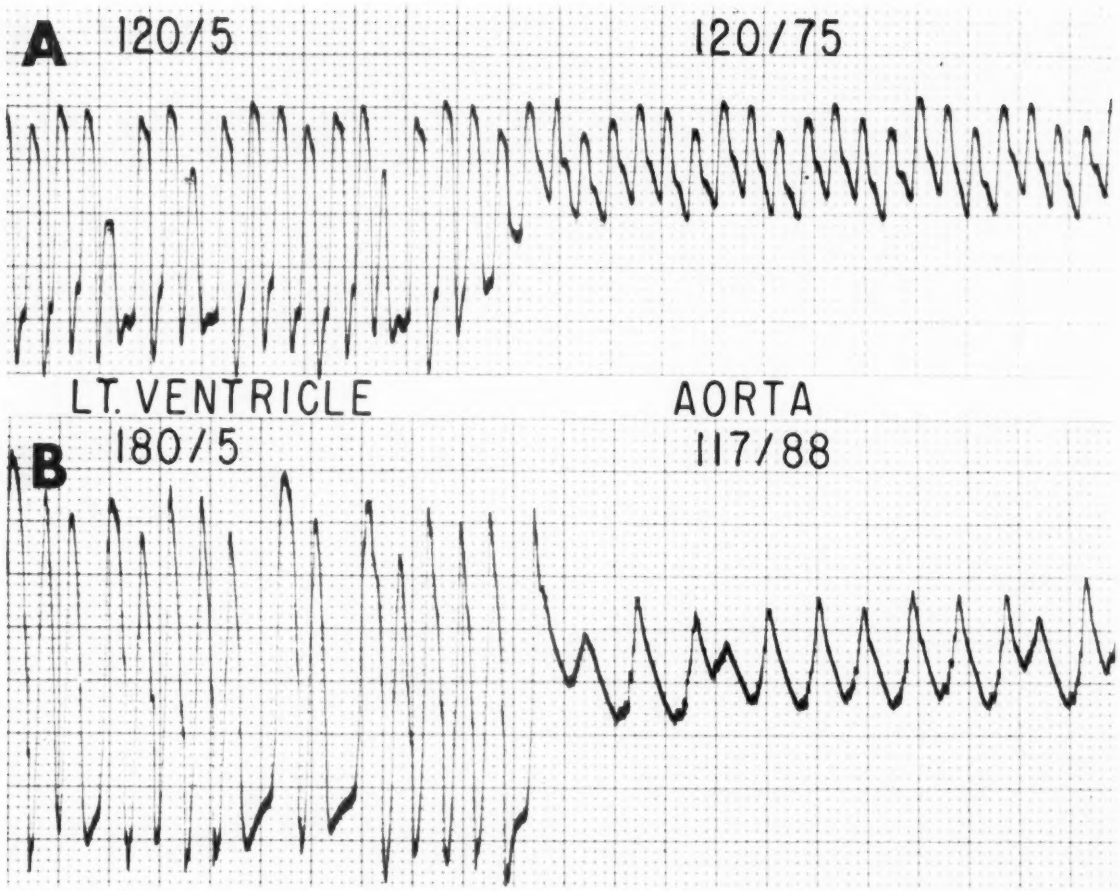

FIG. 3. *Aortic Valve Pressure Gradients.* Pressures taken through PE 205 tube with Stratham P 23AA strain gauge and Sanborn direct recorder. (*A*) Normal gradient. The systolic level shows no change while the elevation in diastolic pressure indicates withdrawal of the catheter through a normal aortic valve. (*B*) Rheumatic aortic stenosis. Systolic gradient establishes the presence of aortic valvular stenosis.

of contrast cardiovascular visualization. Maximal exploitation of the opportunities afforded by this procedure requires the use of special injection apparatus, facilities for rapid serial direct roentgenographic examination (and/or cinefluorography) and means for electrocardiographic and manometric observation and recording. While pressure studies are not essential to left ventriculography, they aid in establishing the position of the tubing and provide valuable information concerning pressure gradients, especially in aortic valvular disease (Fig. 3).

TECHNIQUE

The procedure may be performed on cooperative outpatients since it requires only local anesthesia. The inguinal region is shaved out of consideration for the patient's comfort, since an adhesive pressure dressing is applied following the procedure. A suitable antiseptic solution is applied to the skin and the area is draped so as to expose the femoral triangle. A large drape spread downward over the patient's legs and feet provides a sterile field on which to lay out the guide and tubing before and during insertion. It is necessary that the operator and preferably at least one assistant put on sterile gloves for the introduction and positioning of the tubing. Basically the sterile precautions required are those for venipuncture with the introduction of a sterile catheter.

The femoral artery is located by palpa-

tion and a wheal of local anesthetic is raised in the skin about an inch below the site of intended arterial puncture. A 2 to 3 mm. vertical slit is made through the anesthetized skin and the arterial needle is inserted. Those unfamiliar with the arterial needle puncture may be surprised to learn that it is easier than venipuncture, other things being equal. An effort to obtain blood from the femoral vein will usually confirm this point. The relatively deep location of the femoral artery is offset by its pulsatility and positional stability. Unlike veins, which collapse or tear easily, arteries tend to remain open, thereby permitting an intra-arterial needle tip to advance up the lumen rather than rip out through the back of the vessel. Should through and through penetration of the artery occur, the needle is carefully withdrawn until it snaps into the lumen. Elevation of the tip usually allows satisfactory intraluminal advancement. It is important that the inner stylus (or cutting edge) of the needle be sharp; otherwise the artery will be displaced rather than entered. If for some reason the femoral route is not feasible, the right brachial artery is a satisfactory alternate. Cut-down may be used but increases the local morbidity of the procedure.

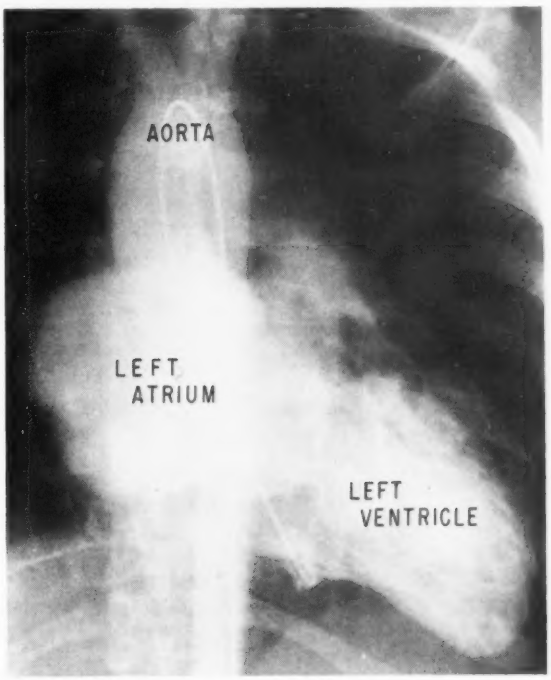

Fig. 4. *Rheumatic Mitral Insufficiency* (twenty year old female, UOMS #26-43-72). Injection into the left ventricle reveals the enlarged left ventricle, normal thoracic aorta and dilated left atrium, which fills through mitral regurgitation. The finding has been entirely reliable in our experience.

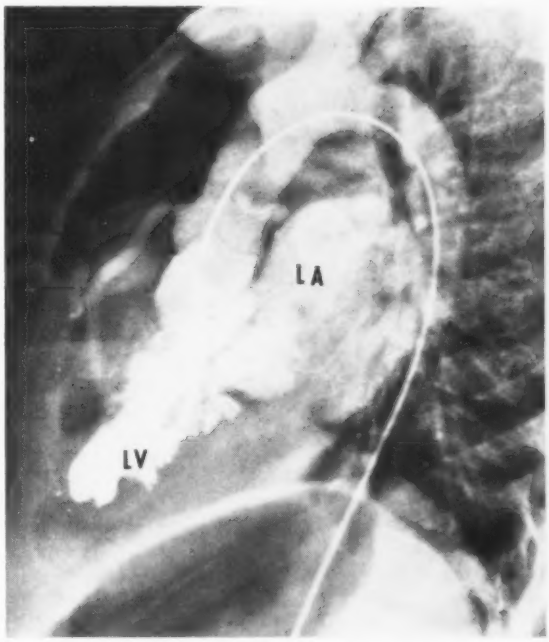

Fig. 5. *Mitral Insufficiency Believed Congenital or Due to Fibroelastosis* (six year old male, UOMS #26-51-73). There had been a murmur of mitral insufficiency since birth (left ventricular hypertrophy on electrocardiography). A lateral roentgenogram during injection into the left ventricle shows ventricular wall thickening, normal aortic valve cusps and possible enlargement of the right coronary artery. Contrast agent regurgitates through the mitral orifice into the dilated left atrium. Serial study in this and frontal projections unequivocally established the presence of serious mitral insufficiency.

It has been pointed out that preparation of the guide and tubing is done in advance. Before insertion, guide and tubing are separated, rinsed clean of sterilizing solution if this has been used and immersed in heparinized saline solution (25 mg. in 500 cc. of normal saline). As will be apparent, the guide and tubing must be measured before actual use. The tubing should be shorter than the guide by a *known* amount (for example, six inches) since, after guide

and tubing are inserted, their relative intravascular positions can be determined only by observing the length of guide projecting beyond the outer end of the tubing. It may aid in the conduct of the procedure if a sterile ruler is available. Measurement is facilitated if the guide and tubing are extended lengthwise on the sterile drapes over the patient's legs. Trial indicates that electroplated length markings are not worth the cost.

As soon as the needle has been introduced and advanced within the artery and the stylus (if used) has been withdrawn, the operator, taking care to avoid undue loss of blood now spurting forth, inserts the tip of the spring through the centrally directed needle. The guide is advanced three or four inches beyond the needle and held in place while the needle itself is withdrawn from the artery, slid the length of the guide and removed. At this juncture and thereafter, observation is maintained and local pressure applied as necessary to insure that blood does not leak from the puncture site. After the needle has been removed, the polyethylene tubing is slipped over the guide (like insulation over a wire) until it passes through the skin and bears against the arterial wall at the site of puncture. Rotation and forward pressure exerted simultaneously on the tubing and

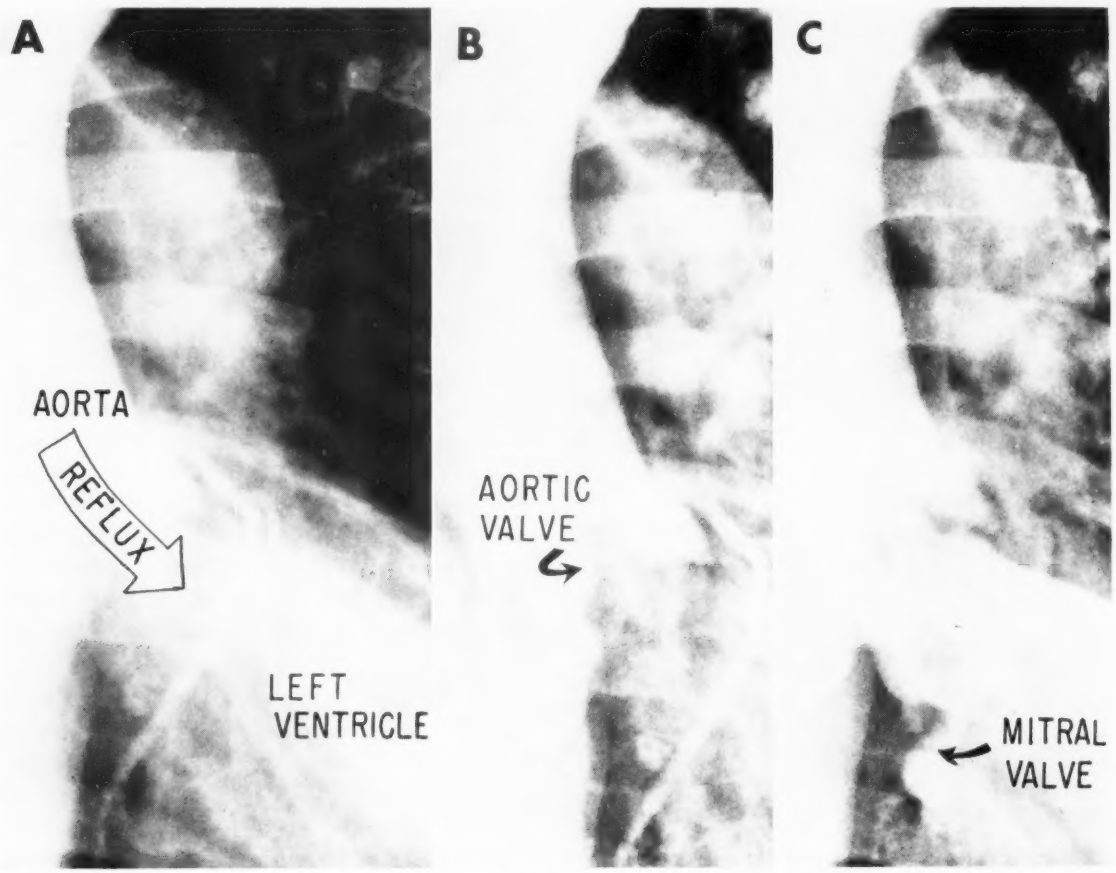

FIG. 6. *Rheumatic Aortic Stenosis and Insufficiency* (forty-two year old male, UOMS #26-68-00). (*A*) Injection into the proximal thoracic aorta reveals definite reflux of contrast material into the left ventricle, establishing the diagnosis of aortic insufficiency. (*B*) A subsequent roentgenogram (same injection) shows superior aspect of aortic valve cusps to be abnormally irregular and rigid in appearance. (*C*) Injection into the left ventricle confirms the foregoing, showing both surfaces of the valve cusps. Calcification and irregularity in the left ventricular wall in the region of the mitral orifice are due to mitral stenosis. The findings were confirmed at autopsy, nine months later.

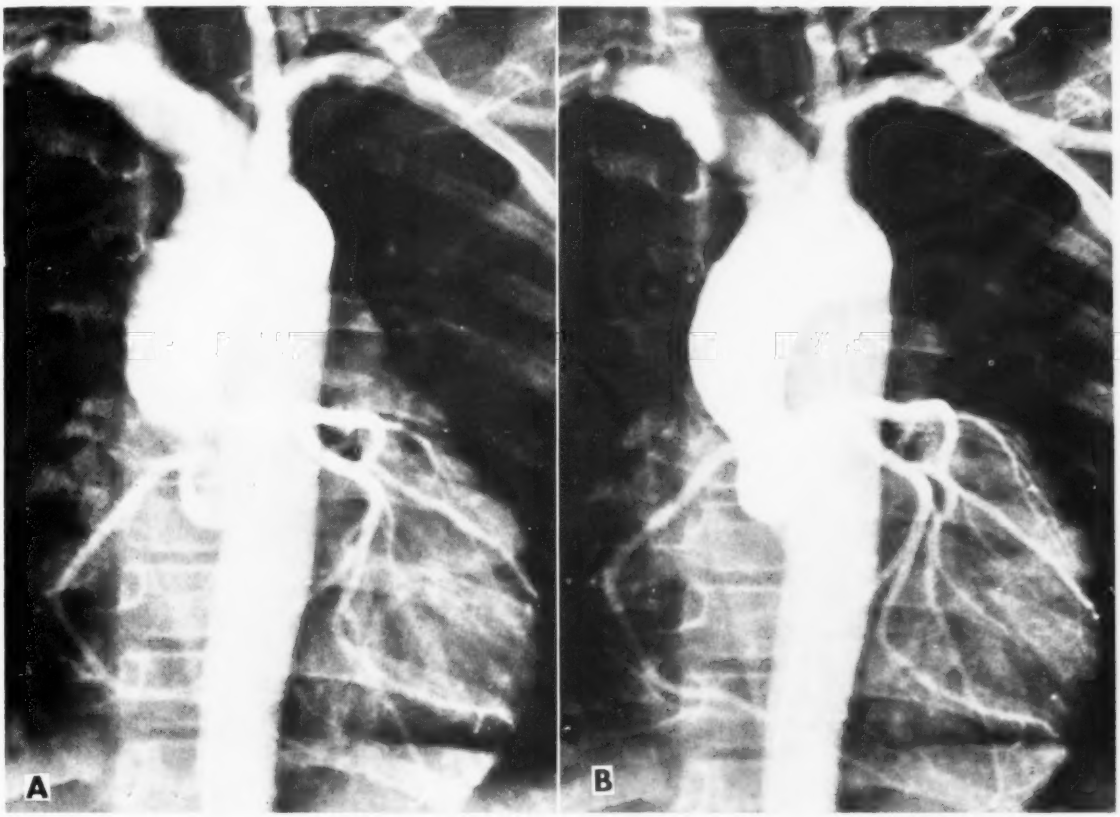

Fig. 7. *Congenital Aortic Stenosis* (eight year old male, UOMS #27-11-84). Supravalvular injection. (*A*) During systole, systolic ejection causes upward ballooning of incompletely segmented aortic valve, similar to dome shape of pulmonary valvular stenosis. Transvalvular pressures were confirmatory. (*B*) During diastole, the valve appears relatively normal. The coronary arteries are normal. The absence of aortic insufficiency demonstrated by this study was of importance in planning the corrective surgery which followed.

guide usually result in prompt passage of the polyethylene tubing into the lumen of the artery. Unless the guide has been inordinately advanced into the artery prior to the introduction of the polyethylene tubing, its outer end will at this point be found to project beyond the hub of the adapter on the outer end of the polyethylene tubing. Thus, it is feasible to advance, withdraw, or otherwise manipulate either or both, as required by subsequent steps in the procedure.

Under fluoroscopic control made possible by the radiopacity of the metallic guide and facilitated by the use of an image intensifier,* the guide and catheter are advanced until the guide reaches the desired position which, for left ventricular passage, is the ascending aorta. Occasional difficulties will be encountered in avoiding the origin of the left brachiocephalic arteries, and in two or three instances we have found it impossible to reach the abdominal aorta because of marked tortuosity or aneurysm of the iliac arteries. The tendency for the guide to catch in the origin of the left subclavian artery can usually be overcome by judicious manipulation and trial variations in the length of guide projecting beyond the end of the polyethylene tubing. Should it prove desirable, it requires but a few seconds to withdraw the guide completely from the polyethylene tubing, wipe off adherent fibrinous material with heparin-saline solution, suitably re-shape the

* If ordinary fluoroscopy is used, a specific individual *not wearing red goggles* should be assigned to guard against inadvertent hemorrhage around or through the tubing.

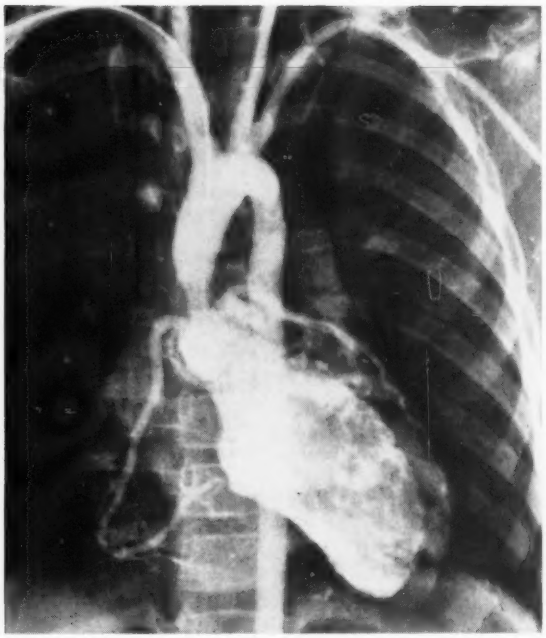

FIG. 8. *Supravalvular Aortic Stenosis, Congenital* (eight year old female, UOMS #26-47-73). An injection into the enlarged left ventricular cavity reveals the presence of a marked narrowing about 2 cm. above apparently normal aortic valves. The constriction coincided with the level of origin of the coronary arteries. At open heart surgery planned on the basis of these findings, an oval Ivalon patch was placed into a vertical incision carried down into the noncoronary sinus of Valsalva. The result has been excellent.[15]

guide (by bending the contained piano wire), and reinsert it through the tubing. During the time when the guide is out, the tubing is cleared, first by allowing blood to flow out of it and, thereafter, by injecting a small amount of heparin-saline solution.

Passage of the aortic valve should be achieved with about two inches of guide projecting beyond the tip of the polyethylene tubing. The projecting guide should be rendered maximally flexible by appropriate withdrawal of the inner piano wire stiffener. Under these circumstances, advancing the instrument will usually result in the tip of the guide assuming a single loop or bend as a result of impingement in an aortic sinus. Aided by slight withdrawal or rotation of the guide, this loop will usually disappear promptly as the flexed tip of the instrument snaps straight, thereby passing between the valve cusps during systole. This having occurred, the guide and polyethylene tubing are advanced well into the ventricular cavity and their relative positions are equalized. The spring guide is then withdrawn and the desired injections or other studies are carried out.

During the time that guide and/or tubing occupy a ventricular location, ventricular premature contractions often occur. Their appearance or disappearance in the electrocardiographic monitor often serves to indicate the moment of transvalvular

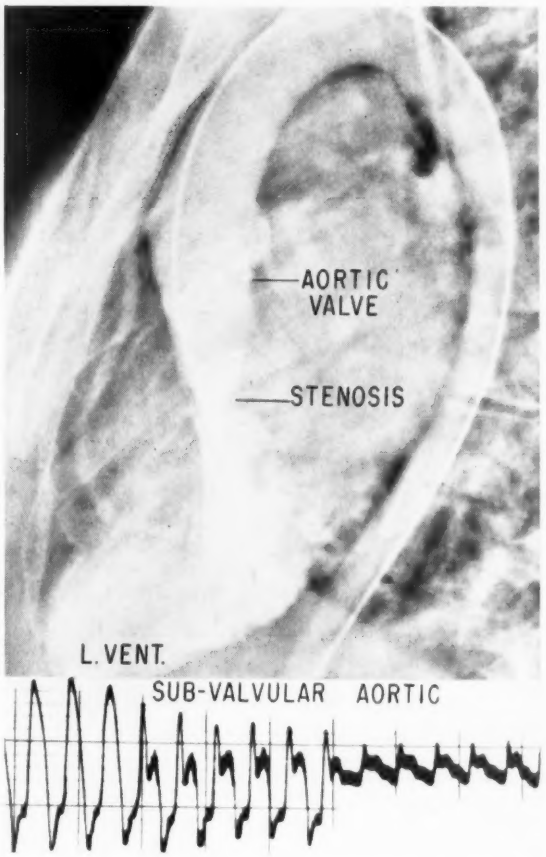

FIG. 9. *Hypertrophic Outflow Occlusion of the Left Ventricle* (fifteen year old female, UOMS #24-57-10). Pressure studies revealed a systolic gradient between the lower left ventricle and the transitional "low pressure" subvalvular portion of its outflow tract. Left ventriculography with injection into the left ventricular cavity reveals a narrowing of the outflow tract and a posterior ridge-like indentation approximately 2 to 3 cm. below the level of normal appearing aortic valve cusps. Autopsy also revealed endocardial fibroelastosis.

passage in either direction. Unless serious aortic stenosis is present, rarely are more than a few seconds required to achieve transvalvular passage by this method. Even in severe aortic stenosis it can usually be accomplished in a few minutes.

The technique affords a useful means for catheterizing the coronary arteries and thereby is a potential cause of myocardial ischemia. Should guide or tubing inadvertently enter a coronary artery, it will be evident on fluoroscopy. It should not be left there inadvisedly. While the catheter lies within the left ventricle, slight adjustment of its position often will result in the disappearance or marked reduction in frequency of associated ventricular premature contractions. This reduction is desirable but not to the extent that protracted manipulation is justifiable. Efforts should be made to minimize the period of time during which the catheter occupies an intraventricular and to a lesser extent an intra-arterial position.

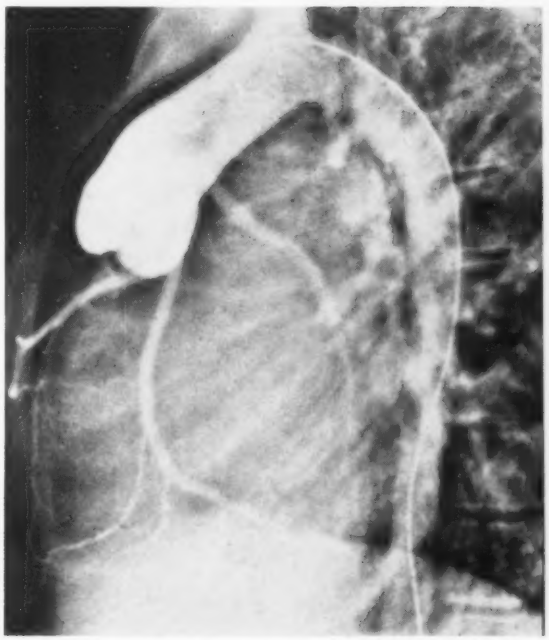

Fig. 11. *Transposition of the Great Blood Vessels* (thirteen year old female, UOMS #17-36-63). Supravalvular injection reveals the far anterior origin of the aorta, a characteristic finding in this condition. The major coronary arteries are well shown. The guided catheter was also passed from the aorta into both right and left ventricles, establishing the presence of an interventricular septal defect.

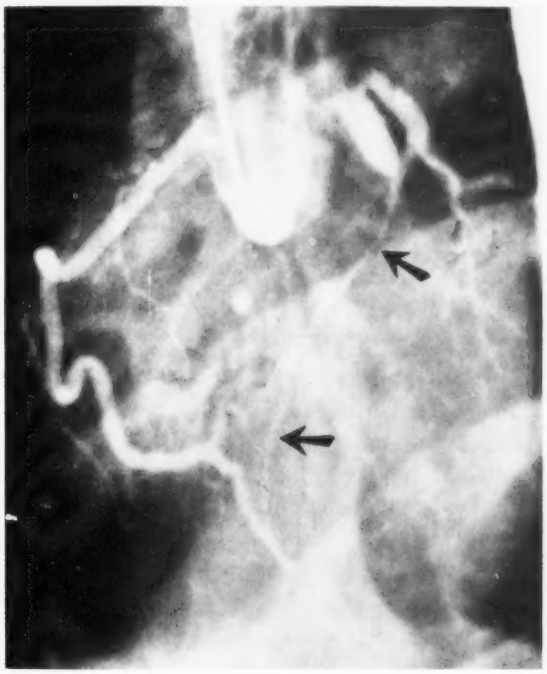

Fig. 10. *Coronary Occlusion* (sixteen year old boy, UOMS #26-17-45). There was electrocardiographic evidence of previous myocardial infarction apparently incurred during the fifteenth year of life. A supravalvular injection of contrast material reveals moderate dilatation of the right coronary artery. There is definite marked narrowing of almost the entire left anterior descending branch. These findings were present on multiple roentgenograms in two projections. Case reported in detail elsewhere.[4a]

Following a preliminary manual trial injection of saline and with the patient in an appropriate position for roentgenography, the desired dose of contrast agent is rapidly injected through the catheter concomitant with the beginning of a series of roentgenographic exposures. We have used doses of contrast agent ranging between 5 and 50 cc. and have attempted to achieve an injection not exceeding one to two seconds in duration. Though we generally employ the lowest viscosity contrast media available (urokon sodium 70 per cent or ditriokon, a new agent obtained through the courtesy of Mallinckrodt Chemical Works), it is still profitable to employ an

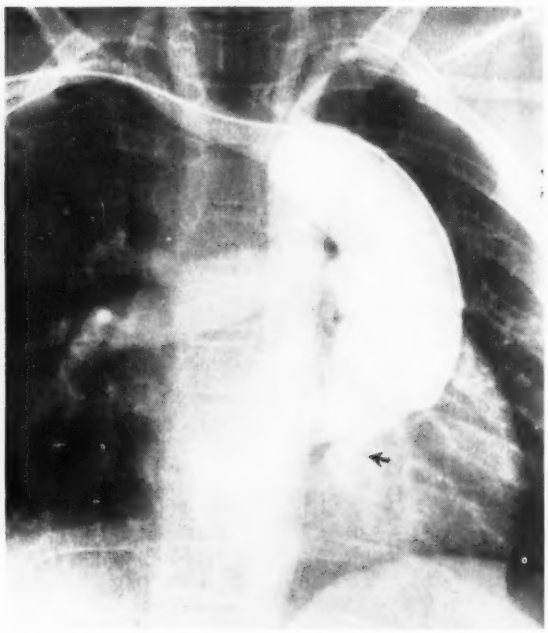

FIG. 12. *Corrected Transposition with Interventricular Septal Defect* (ten year old male, UOMS #22-26-06). Contrast substance fills the outflow tract of the right ventricle reached through retrograde catheterization of the aortic valve. A small jet crosses into the left ventricular outflow tract through a high interventricular septal defect (arrow). Characteristic reversed origin of the great vessels is present. In this roentgenogram, the pulmonary artery is obscured by the proximal aorta.

automatic injection device. The simple, low-cost, high-performance Shipps unit[13] has proved satisfactory in our hands for this purpose. If an extra length of connecting tubing is required, this should be capable of withstanding the injecting force without distending, and thereby cushioning or slowing, the injected contrast medium. It must be obvious that the purpose of a rapid injection rate is a rapid delivery rate, not a rapid syringe emptying rate *per se*. Filming should begin with, or prior to, the beginning of the injection and continue for at least six or more seconds. Thereafter the patient's own blood is allowed to flush out the contrast agent remaining in the tube and a few cubic centimeters of heparin-saline are injected to prevent clotting.

Connection to a suitable manometer allows the recording of intraventricular pressures and, during withdrawal of the tubing, serves to indicate the transition to a supravalvular position. Figure 3, *A* and *B* reveals the characteristic difference between aortic and ventricular pressures in a normal patient and one suffering from aortic valvular stenosis. Unless a biplane film changer is used, circumstances usually warrant a second intraventricular injection, which should, of course, be accomplished prior to catheter withdrawal. It is desirable routinely to perform a third injection into the proximal aorta just above the valves. If pressure monitoring is not done or proves insufficient, catheter location can be checked by fluoroscopy either during the slow injection of a small amount of contrast substance or following the reinsertion of the spring guide. In connection with supravalvular injections, care should be taken to prevent the entire, undiluted bolus of contrast agent from entering a coronary or carotid artery.

After needed studies have been completed, the catheter is withdrawn from the patient and firm pressure is applied to the puncture site. Usually a few minutes' pressure suffices to provide complete hemostasis but, in any event, an elastoplast dressing incorporating a sterile sea sponge over the puncture site is applied and the patient is instructed to watch for possible future bleeding at the site of puncture.

It has actually taken longer to describe the procedure than it often takes to perform it. Fifteen minutes is a feasible start-to-finish time for a trained operator with adequate technical support. Causes of delay are: (a) inability to get into the femoral artery (remedy—try the other femoral artery); (b) inability to get the guide past the left subclavian or carotid arteries (remedy—try bending the tip of the guide); and (c) inability to get past the aortic valves (remedy—skill, luck, and reasonable patience).

The roentgenographic technique is straightforward. A slight increase in exposure compared to ordinary chest roentgenography is desirable in order to compensate for the added radiopacity of the

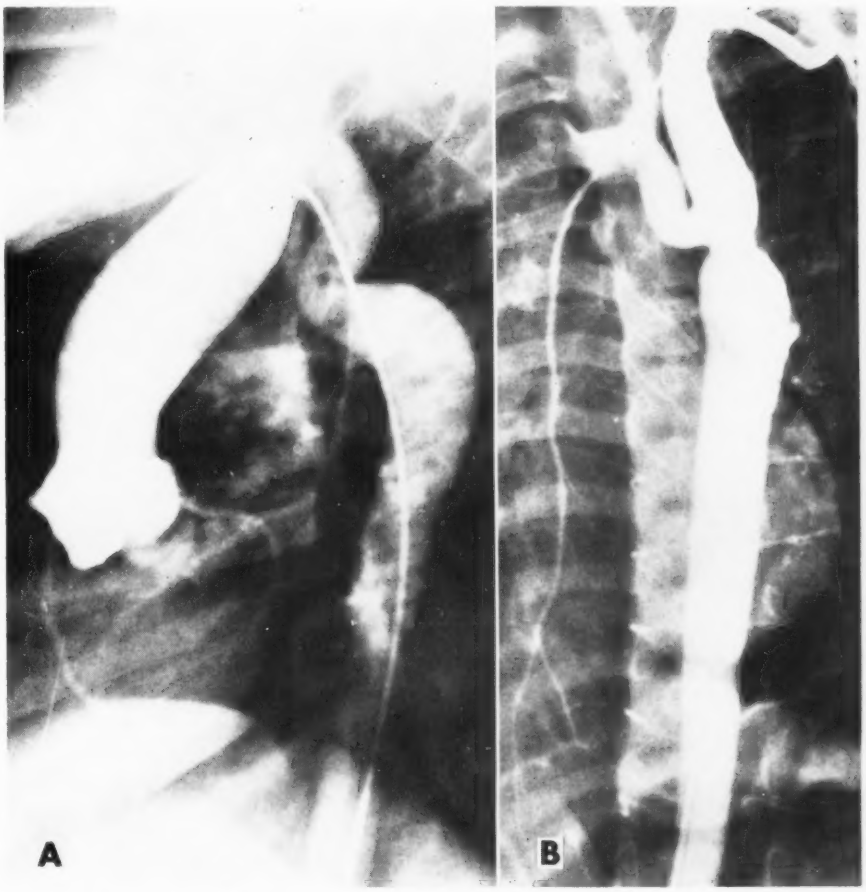

Fig. 13. *Coarctation of the Aorta.* (*A*) Preoperative examination clearly reveals the abnormal anatomy (seven year old male, UOMS #26-23-07). (*B*) Postoperative injection into the dilated proximal left subclavian artery shows that the concentric narrowing at the site of previous surgery was not as important a limiting factor as the hypoplastic portion of the aortic arch between the points of origin of the left common carotid and subclavian arteries (four year old male, UOMS #25-15-33).

contrast agent. Other things being equal, short exposures give better detail since intra-arterial blood velocities in excess of 100 cm. per second occur during left ventricular ejection.[5] It has been our practice to use millisecond exposures whenever possible.[6] To date, our roentgenographic recording has been accomplished by means of an Automatic Seriograph or Fairchild Roll Film Cassette, devices which afford direct roentgenography at two exposures per second. Although a more rapid film changer frequently would have been used had it been available, it is unlikely that the two-per-second limitation led to missed diagnoses in this series. Biplane film changers are, in my opinion, overrated, prohibitively costly mechanical devices which must never be allowed to substitute for professional competence. The safety of newer contrast agents makes their use unnecessary while the need for operational flexibility and films of optimum quality makes them undesirable. Let further progress in film recording techniques be in the direction of bimodal rather than biplane apparatus. Cinefluorography in conjunction with four-per-second direct serial roentgenography constitutes a reasonable approach to the problem; the former provides a more lucid demonstration of the course and character of blood flow and the latter gives a far superior demonstration of anatomic detail. Gensini and I are cur-

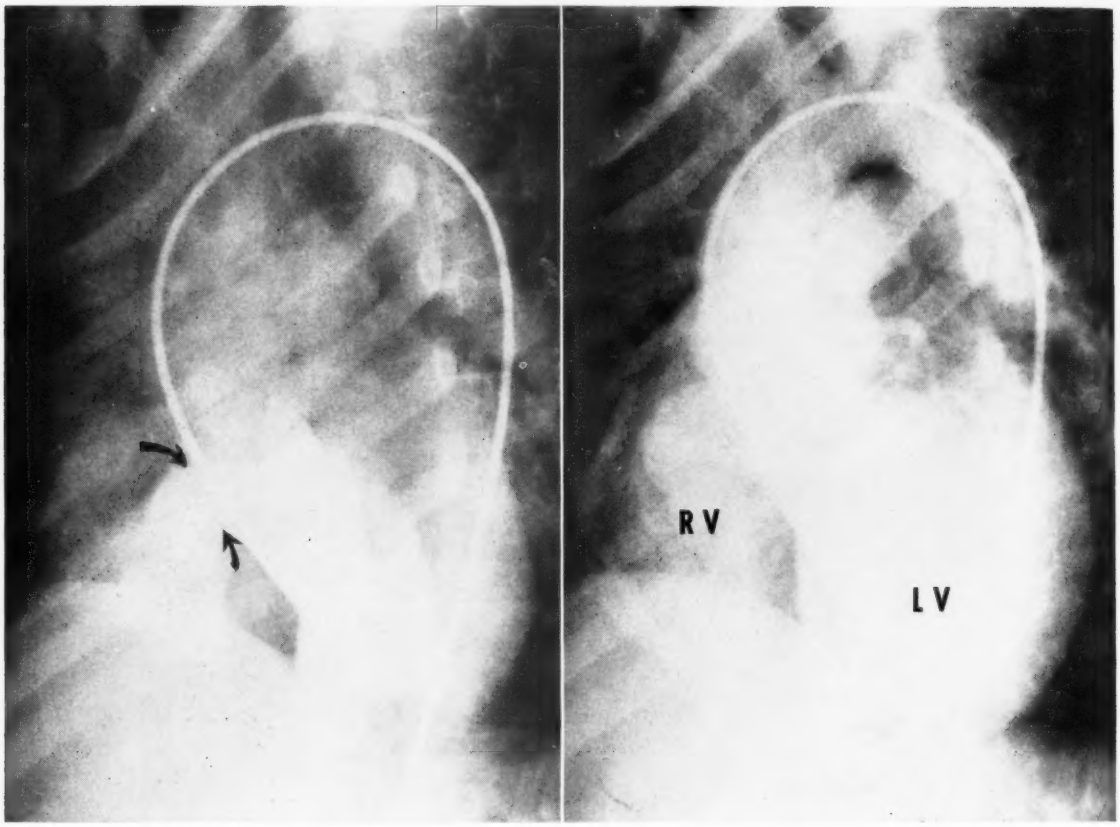

FIG. 14. *Interventricular Septal Defect* (eight year old female, UOMS #20-73-46). Two exposures made at half-second intervals disclose opacification of the left ventricle and directly demonstrate a left to right shunt through a high interventricular septal defect (arrows). The presence, location, and estimated size of the defect were confirmed at subsequent open heart repair. Left ventriculography offers the best available means for preoperative demonstration of interventricular defects.

rently engaged in a systematic and, we hope, objective evaluation of the relative contributions of the two recording techniques.[8] Were we forced to chose one or the other, our present choice would be direct roentgenography as opposed to movie techniques. It is apparent, however, that the approaches are complementary and not competitive. Currently the use of *both* cinefluorography and direct serial roengenography requires an additional injection of contrast agent. The safety of the newer media makes this feasible, just as it reduces the need for cumbersome and costly biplane film changers.

COMPLICATIONS AND HAZARDS

We have used the above described procedure in over 110* patients. One patient, a two year old child with tetralogy of Fallot, died of cardiac arrest during recovery from general anesthesia following an uneventful procedure. Autopsy revealed no cause for the arrest. An elderly decompensated patient died of ventricular fibrillation which began during a supravalvular aortic injection. Her death was clearly related to the contrast agent and not the means of injection. Severe rheumatic mitral and aortic valvular disease was found at autropsy. In a nine year old child with a high interventricular septal defect and pulmonary hypertension, transient hemiplegia appeared eight hours after the study. It is likely that this resulted from inadequate heparinization and a prolonged procedure. Dehydration may have played a role. The patient subsequently recovered. Another patient who developed

* Total number of studies done through April 21, 1960.

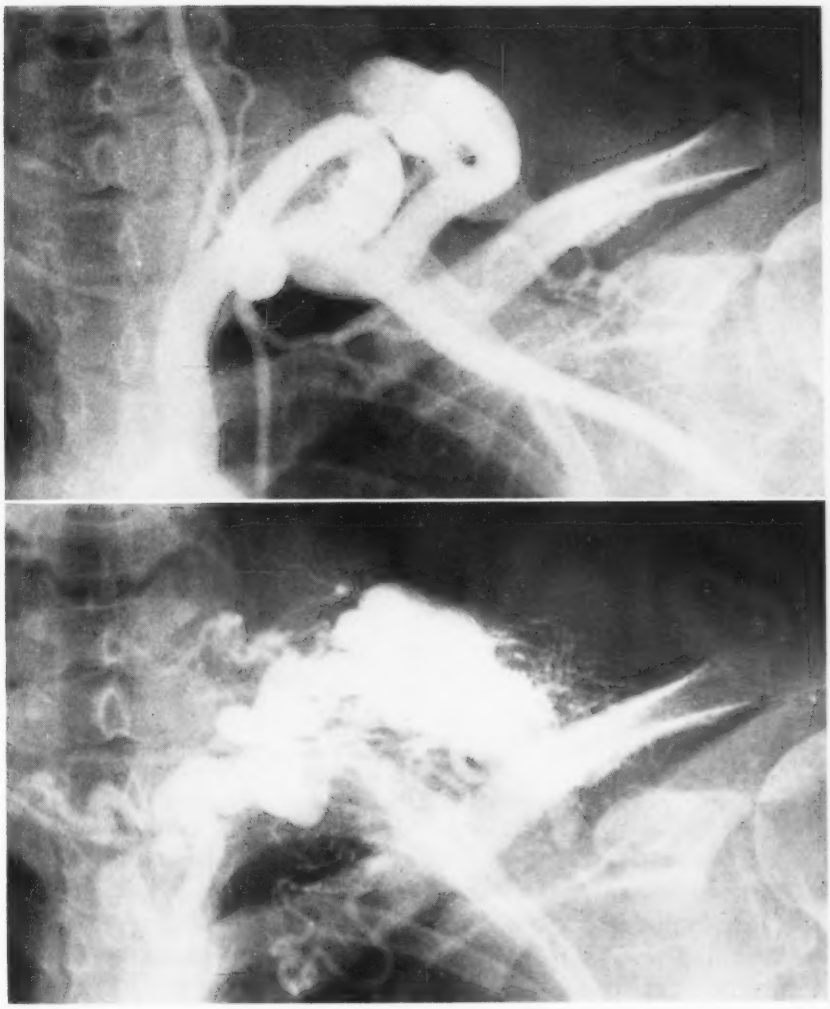

Fig. 15. *Arteriovenous Fistula* (fifty-four year old female, UOMS #27-29-54). A palpable, bruit-producing lesion had been present in the left scapular region for at least twelve years. Two roentgenograms following the intra-aortic injection of ditriokon demonstrate the massively dilated abnormal vessels constituting this fistula, evidently supplied by a dilated transverse cervical artery and drained via the azygos system of veins. Such studies are simple to perform and anatomically superior to any other method, including postmortem study.

hemiplegia several hours after aortic catheterization was found at operation to have a chronic subdural hematoma, suspicion of which had occasioned the examination. Three or 4 patients suffered the temporary discomfort of local hematomas; and postpuncture bleeding which was not detected promptly caused shock during the recovery of a young patient examined under general anesthesia. This complication is entirely preventable. It is believed that with careful technique, adequate heparinization, the avoidance of a prolonged procedure and the use of local anesthesia, this technique is about as safe as conventional angiocardiography.

Since in cooperative patients local anesthesia suffices, the procedure may be done on an outpatient basis. Patients are kept under observation until they are able to walk freely without causing bleeding, usually ten to fifteen minutes following application of the dressing. Prophylactic penicillin has been used routinely and infection has not occurred.

The hazards of this procedure would appear to be those of retrograde thoracic aortography—ideally, amounting to the

FIG. 16. *Carcinoma of the Uterus* (thirty-nine year old female, UOMS #27-54-93). Injection made with catheter tip at aortic bifurcation and inflated blood pressure cuffs on both thighs. Pelvic (including uterine) arteries are clearly revealed. Subsequent exposures demonstrated direct opacification of an asymmetric right-sided uterine tumor which had evidently caused the lateral dislocation of the right external iliac artery shown in this view. The findings were confirmed at subsequent exploratory surgery.

risk offered by the contrast agent itself plus the slight risk of mechanically triggering an undesirable ventricular arrhythmia. Physicians performing contrast visualization, especially if general anesthesia is used, are obligated to be materially and psychologically prepared for emergency thoracotomy. In connection with other roentgenologic procedures, the author has done emergency thoracotomy and cardiac massage in 4 patients, 2 of whom recovered completely.

Preliminary experience gained with the use of a new contrast agent warrants brief comment. Ditriokon (Mallinckrodt) is a water solution containing approximately equal amounts of diatrizoate sodium (hypaque) and diprotrizoate sodium (miokon). While iodine content and, therefore, radiopacity are additive in the mixture, viscosity is not, in this case being far lower than that of hypaque M 90 per cent or cardiografin and slightly higher than that of urokon sodium 70 per cent. Our experience in the general angiographic applications of ditriokon consists of over 150 cases.[7]

RESULTS

The value of the procedure is indisputable. By affording a simple means for measuring the pressure gradient across the aortic valve and providing an objective, direct means for demonstrating aortic and mitral insufficiency, it has become essential to the preoperative study of candidates for open heart surgery at our institution. It allows the direct demonstration of a variety of congenital and acquired cardiac lesions, which previously were best approached by crude and inferential techniques such as the use of stethoscopes. The unique problems of open heart surgery have given a challenge to the lagging standards of diagnostic adequacy. For example, slight aortic insufficiency such as would probably escape detection by ordinary clinical methods of examination can cost the life of the patient

undergoing open heart surgery.[14] Subclinical aortic regurgitation, yesterday's "false positive" finding, is an important object of today's diagnostic search. Left ventricular and aortic injections of contrast media not only provide important hemodynamic information concerning aortic valvular competence; they represent the best available approach to the study of abnormal valvular anatomy in the living patient short of direct inspection. While direct roentgenographic examination of the mitral valve still leaves much to be desired with respect to the anatomic information gained, left ventricular injection of opaque substances provides the only available direct means for demonstrating the actual regurgitation in mitral insufficiency, long a diagnostic problem in the selection of patients for mitral valvular surgery (Fig. 4 and 5).

Through ready access to major aortic branches, left-sided selective visualization has simplified otherwise difficult problems in visceral, cerebral and peripheral arteriography. In obviating the need for arteriotomy, it has reduced the need for hospitalization otherwise involved in such studies. In providing a simple highly effective method for pelvic arteriography, it solves the problem of placental visualization and has proved capable of demonstrating uterine tumors. The human body is fully packed with arteries large enough to be visualized by contrast roentgenography. Thus, in a broad sense, contrast cardiovascular visualization may give us means for the study of many gross and certain functional defects of the body which have not received such consideration in the past. To the extent that arteriography becomes simpler, safer and more accurate, it will continue to increase in importance. Its increasing importance in neurosurgical diagnosis serves as a contemporary indicator; its future importance in coronary disease will be a case in point in the years to come.

Like any other, the method described here has its shortcomings. Instrumental advances or alternatives, such as the ingenious, flexible end-loop catheter recently described by Bellman *et al.*[2] and applied by Williams and his colleagues,[16] will no doubt be of value in minimizing the risk of trauma, embolization or hemorrhage. To date, spring-guided catheters have rarely reached the left atrium, in part because efforts in this direction have not been exerted. Partly for this reason, the method's achievements with respect to the aortic valves are not paralleled at the mitral region. Further experience will undoubtedly serve to increase our ability to see and thereby learn more about this valve.

This report has primarily been concerned with a detailed technical description of a procedure. Figures 4–16 illustrate some of its many useful applications.

CONCLUSIONS

Percutaneous, spring-guided catheterization of the left ventricle, the aorta and systemic arteries is a reasonably safe, simple and effective procedure for obtaining detailed anatomic and physiologic information of investigative and clinical importance. The ease with which it can be carried out on unanesthetized outpatients makes it appear likely that this or a related method will receive widespread application in the future. Considering the efforts to which many workers have gone in order to obtain catheter access to the aorta and left heart chambers (transbronchial, transseptal, transthoracic, trans-sternal needle puncture of the left heart, etc.), the method described here and credited gratefully to Prioton, his colleagues and Seldinger seems almost too good to be true.

SUMMARY

A detailed description is presented of the use of a flexible coilspring guide which gives access to the left ventricle and systemic arteries by means of a percutaneous retrograde femoral-aortic approach suitable for outpatient use.

The procedure is useful not only in diagnostic contrast visualization but also as a means for obtaining hemodynamic data

and a route for selective drug administration.

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ROENTGENOLOGIC DIAGNOSIS OF CONGENITALLY CORRECTED TRANSPOSITION OF THE GREAT VESSELS*

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CONGENITALLY corrected transposition of the great vessels can best be defined as a malformation in which the aorta and pulmonary artery are transposed in relation to each other but in which the flow of blood is in the physiologic direction. It must be sharply differentiated from complete transposition of the great vessels in which the flow of blood is such that the unoxygenated blood from the right ventricle passes into the aorta and the major circulation, while oxygenated blood from the left ventricle returns to the minor circulation.

In congenitally corrected transposition, in addition to the malposition of the great vessels, there is an inversion of the ventricles. The anatomic left ventricle is in the position of the normal right ventricle and the anatomic right ventricle is situated where the left ventricle is normally positioned. As a result, the flow of blood is from the right atrium to the anatomic left ventricle to the pulmonary artery and from the left atrium to the anatomic right ventricle to the aorta. Oxygenated blood, therefore, passes into the systemic circulation and deoxygenated blood into the lungs.

This condition is of importance to radiologists for the following reasons: (1) It is a relatively frequent occurrence, although it has been recognized clinically only recently; (2) it is usually associated with other defects, many of which can be corrected surgically; (3) its recognition may be essential to the adequate repair of the associated defects; and (4) the definitive clinical diagnosis is most satisfactorily made by recognition of the roentgenologic features, especially by angiocardiography.

ANATOMY

Figure *1A* demonstrates in diagrammatic form the essential anomaly in the most common form of complete transposition. The cause of the intense cyanosis and short life span in these children is obvious. Almost 90 per cent of infants with complete transposition succumb within the first year of life.

The most common form of congenitally corrected transposition is diagrammed in Figure *1B*. In this situation the physiologic flow of blood is maintained and, in the absence of other cardiac anomalies, a normal life span can be expected. However, congenitally corrected transposition without associated anomalies appears to be quite rare, or at least is seldom recognized.

The fact that the pulmonary pumping ventricle in corrected transposition is truly the anatomic left ventricle has been demonstrated.[4] There is no infundibulum and no crista supraventricularis in this ventricle. Trabeculation is minimal. The valve between the right atrium and this ventricle is of mitral type. This valve is situated close to the pulmonary valve. On the other hand, the systemic pumping ventricle (anatomic right ventricle) shows a well defined infundibulum and crista supraventricularis. The tricuspid valve is found on this side.

A schematic representation of the anat-

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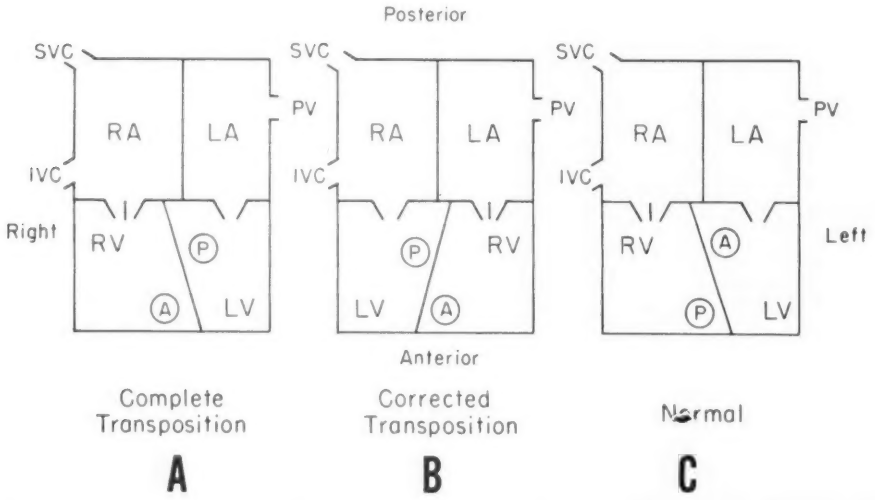

FIG. 1. Schematic representation of the essential abnormalities in (*A*) complete transposition and (*B*) congenitally corrected transposition, as compared with the normal (*C*).

omy of the cardiac chambers and the great vessels in congenitally corrected transposition is shown in Figure 2. The pulmonary artery arises medially and the pulmonary valve is lower than in the normal. The aorta arises along the left lateral border of the heart and will, therefore, usually make up the left upper border of the cardiac silhouette in a frontal roentgenogram. The aortic valve is higher than the pulmonary valve. This is the reverse of the normal situation. The pulmonary pumping ventricle often has an unusual tail-like projection toward the cardiac apex, perhaps due to the absence of the conus.

In the lateral projection, the ascending aorta is displaced anteriorly and the pulmonary artery arises somewhat more posteriorly than is ordinarily seen. However, this is not as striking as in complete transposition. As a result, the origins of the great vessels often lie in approximately the same plane in this projection, the aortic root, however, being to the left of the pulmonary artery. In other examples, the aorta lies slightly but distinctly anterior to the pulmonary artery.

The pulmonary pumping ventricle is anteriorly placed. Most of the systemic pumping ventricle is posterior, although this ventricle has an anterior portion along its superior lateral aspect.

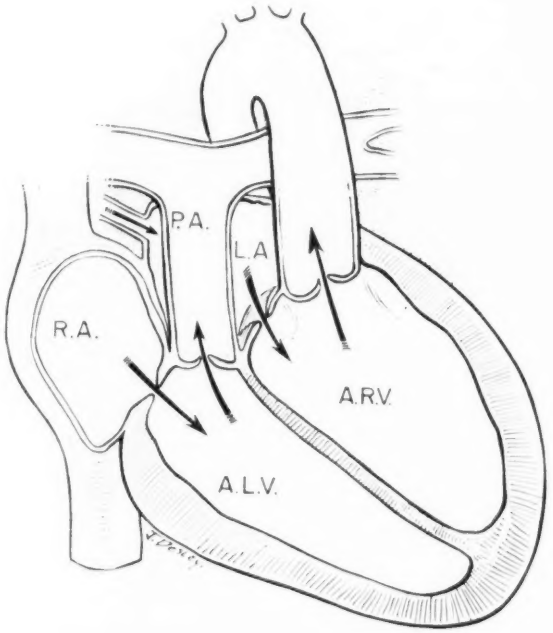

FIG. 2. Pathologic anatomy in congenitally corrected transposition as seen in the frontal plane. Note the low medial position of the pulmonary artery. The ascending aorta arises from the left lateral border of the heart. The mitral valve is on the right and the tricuspid valve on the left. The right atrioventricular valve is located close to the pulmonary valve. The left atrioventricular valve is separated from the aortic valve by the crista supraventricularis. The aortic valve lies higher than the pulmonary valve. A.L.V.—anatomic left ventricle; A.R.V.—anatomic right ventricle; L.A.—left atrium; R.A.—right atrium; P.A.—pulmonary artery.

TABLE I

ANOMALIES ASSOCIATED WITH CONGENITALLY CORRECTED TRANSPOSITION OF THE GREAT VESSELS

Diagnosis	Number of Patients	Patients
Interventricular Septal Defect	9	K.B., T.G., G.R., W.N., D.K., D.T., W.D., H.R., G.W.
Single Ventricle	9	P.Sa., T.P., N.B., M.K., F.T., R.W., G.T., S.V., P.Si.
Tetralogy of Fallot	8	M.S., P.H., J.G., M.St., T.M., K.R., J.D., R.H.
Interventricular Septal Defect and Pulmonary Stenosis	5	K.N., H.A., M.Sc., B.S., J.G.
Pulmonary Stenosis	3	J.K., D.T., J.N.
Dextrocardia with Interventricular Septal Defect	2	G.S., G.W.
Patent Ductus Arteriosus	1	J.E.
Reversing Patent Ductus Arteriosus	1	W.S.
Single Ventricle with Interruption of Arch of Aorta and Reversing Patent Ductus Arteriosus	1	L.D.
Single Ventricle, Atresia of Right Atrioventricular Valve, Coarctation of Aorta, Patent Ductus Arteriosus and Atrial Septal Defect	1	G.G.

The coronary arteries are also inverted. The anterior descending branch of the anatomic left coronary artery is placed anteriorly and to the right over the pulmonary pumping ventricle.

INCIDENCE

Although this condition was recognized first by von Rokitansky[6] in 1875, it was considered very unusual until recently. As late as 1954, Lev[5] reported the anomaly to be "exceedingly rare." Cardell[3] in 1956 found 24 cases in the literature and added one. Since then other case reports and reviews have been published, bringing the total, at present, to about 100 cases. The largest single group reported to date was from this institution in 1957; 17 patients were described.[1]

In almost all reported cases congenitally corrected transposition has been associated with other cardiac anomalies although an occasional case of isolated corrected transposition has appeared in the pathology literature.[5] Recently, a child with isolated corrected transposition was seen at Johns Hopkins Hospital.[2]

The disease is evidently more common than these reports would indicate. A group of 32 cases is to be reported from the Mayo Clinic.[7] The cases to be discussed here include 32 hitherto not recorded in the literature. The diagnosis is now being made with increasing frequency at other centers.

MATERIAL

From a series of more than 60 patients in whom this diagnosis has been made at the Variety Club Heart Hospital of the University of Minnesota, a group of 40 has been selected for analysis of the roentgenographic findings.

Included are 28 patients in whom a definitive diagnosis was made by angiocardiography. In 3 of these patients the diagnosis was confirmed at operation, and in another at necropsy. In 2 additional patients angiocardiography performed following operation revealed the malformation.

In another 4 patients the diagnosis was established by cardiac catheterization alone. Of these, one had been operated upon. Many of the patients in this series underwent both catheterization and angiocardiography. The total number of patients in whom the diagnosis was established or suggested at catheterization was eleven.

Four cases are included in which the diagnosis was made only at operation and 2 in which the diagnosis was established at necropsy.

Included also in this series are 8 patients previously reported from this hospital.[1] Five of these patients had angiocardiography.

There are 22 males and 18 females in the group in which roentgenologic study was made. The age range is from three months (G.W.) to forty-four years (M.S.). Besides M.S., there are 3 other adults in this series, J.D., twenty-one, H.R., thirty-two and H.A., thirty-three years old.

All of the patients in this study had other congenital cardiac defects in addition to congenitally corrected transposition. These are listed in Table 1. For the purposes of this tabulation "tetralogy of Fallot" is defined as ventricular septal defect, pulmonary stenosis and right to left shunt through the ventricular septal defect. The cases listed as having ventricular septal defect with pulmonary stenosis showed evidence of left to right shunt only, there being no peripheral oxygen desaturation. The category "single ventricle" includes 2 cases previously diagnosed as "ventricular septal defect with small left ventricle,"[1] and also patients with a large ventricular septal defect with bidirectional shunt or Eisenmenger complex. All of these patients showed evidence of peripheral oxygen desaturation. In cases where catheterization was performed, the oxygen saturation in the pulmonary pumping ventricle was essentially or nearly equal to that in the femoral artery. In most such cases there is a small systemic pumping ventricle and a large ventricular septal defect. However, the left sided atrioventricular valve overrides the defect. Consequently, there is a mixing of the blood returning from the periphery and from the lungs within the ventricular cavity. These patients present the other anatomic features common to cases of congenitally corrected transposition.

CLINICAL AND ELECTROCARDIOGRAPHIC FINDINGS

A previous report from this institution detailed the auscultatory and other clinical data and the electrocardiographic findings in a group of 17 patients with congenitally

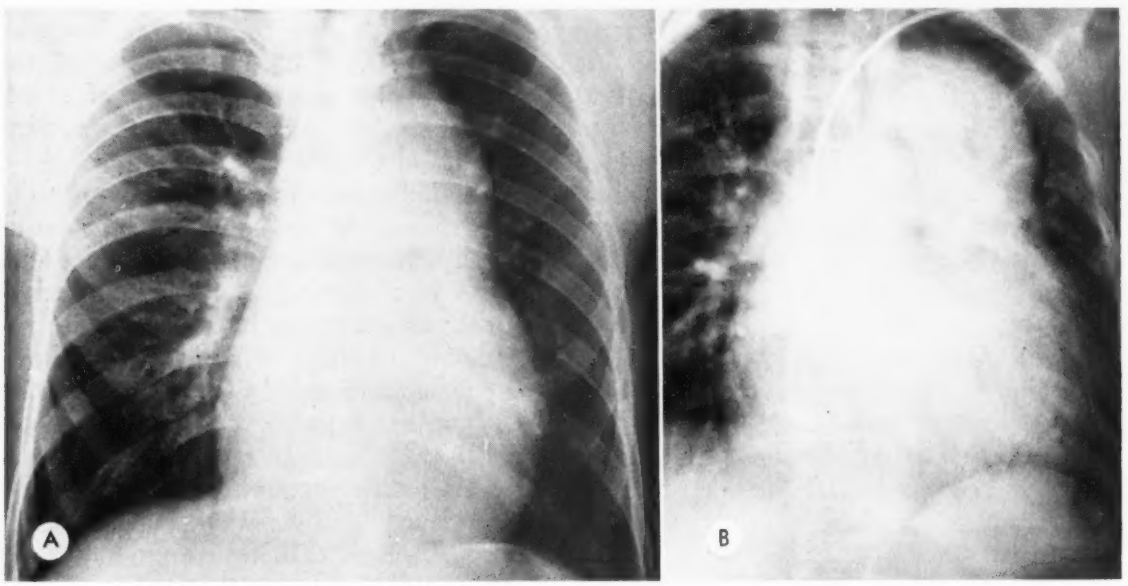

FIG. 3. Congenitally corrected transposition of the great vessels, complete heart block, and ventricular septal defect in a seventeen year old male. (*A*) In the conventional roentgenogram note especially the ascending aorta along the upper left border of the heart. (*B*) Late angiogram shows left atrium, systemic pumping ventricle and aorta.

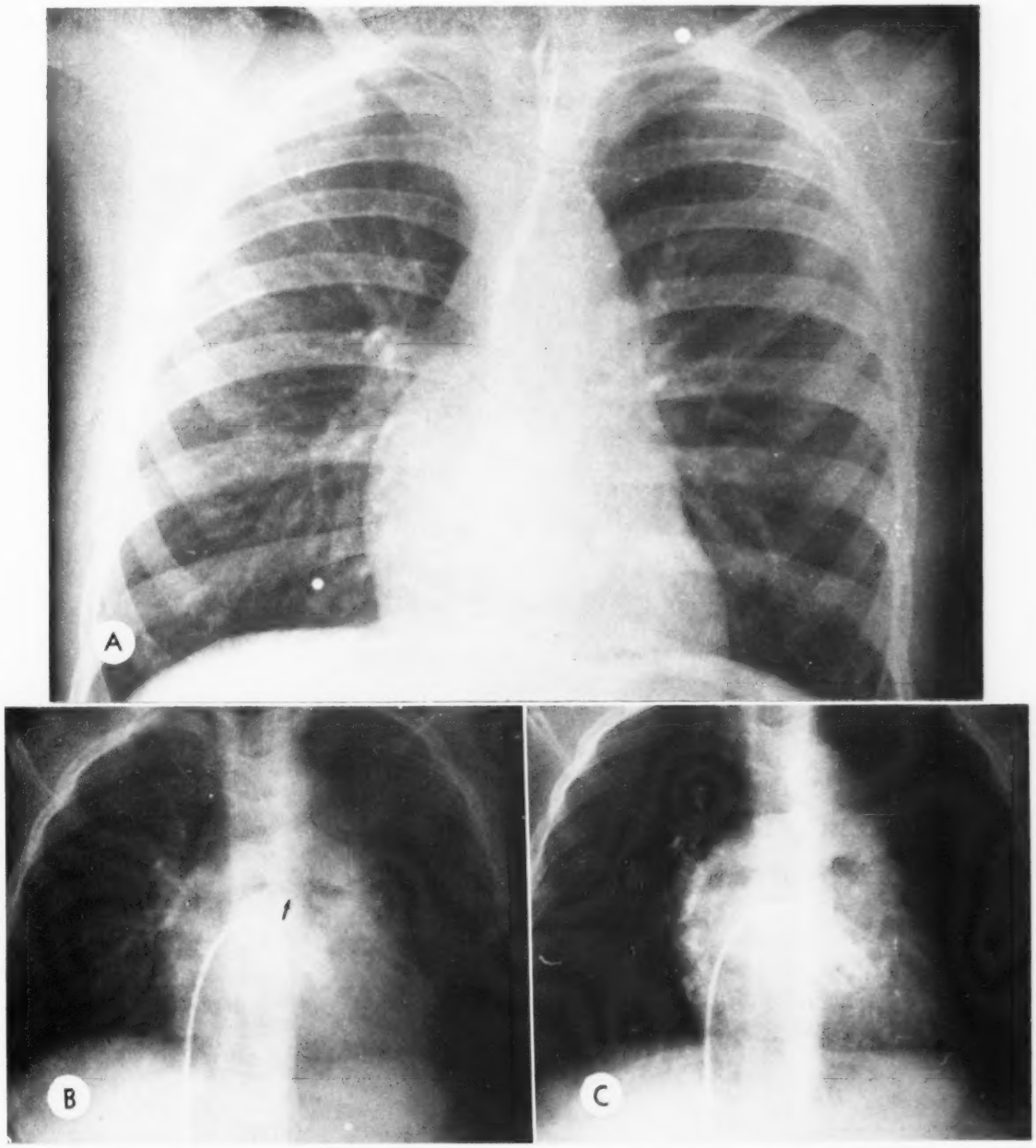

Fig. 4. Congenitally corrected transposition of the great vessels with tetralogy of Fallot in a nine year old male. (*A*) Note the ascending aorta making up the left upper border of the cardiac silhouette and the indentation of the medially placed pulmonary artery on the esophagus. (*B*) Arrow denotes the medially placed pulmonary artery. (*C*) Opacified ascending aorta is seen laterally to the left.

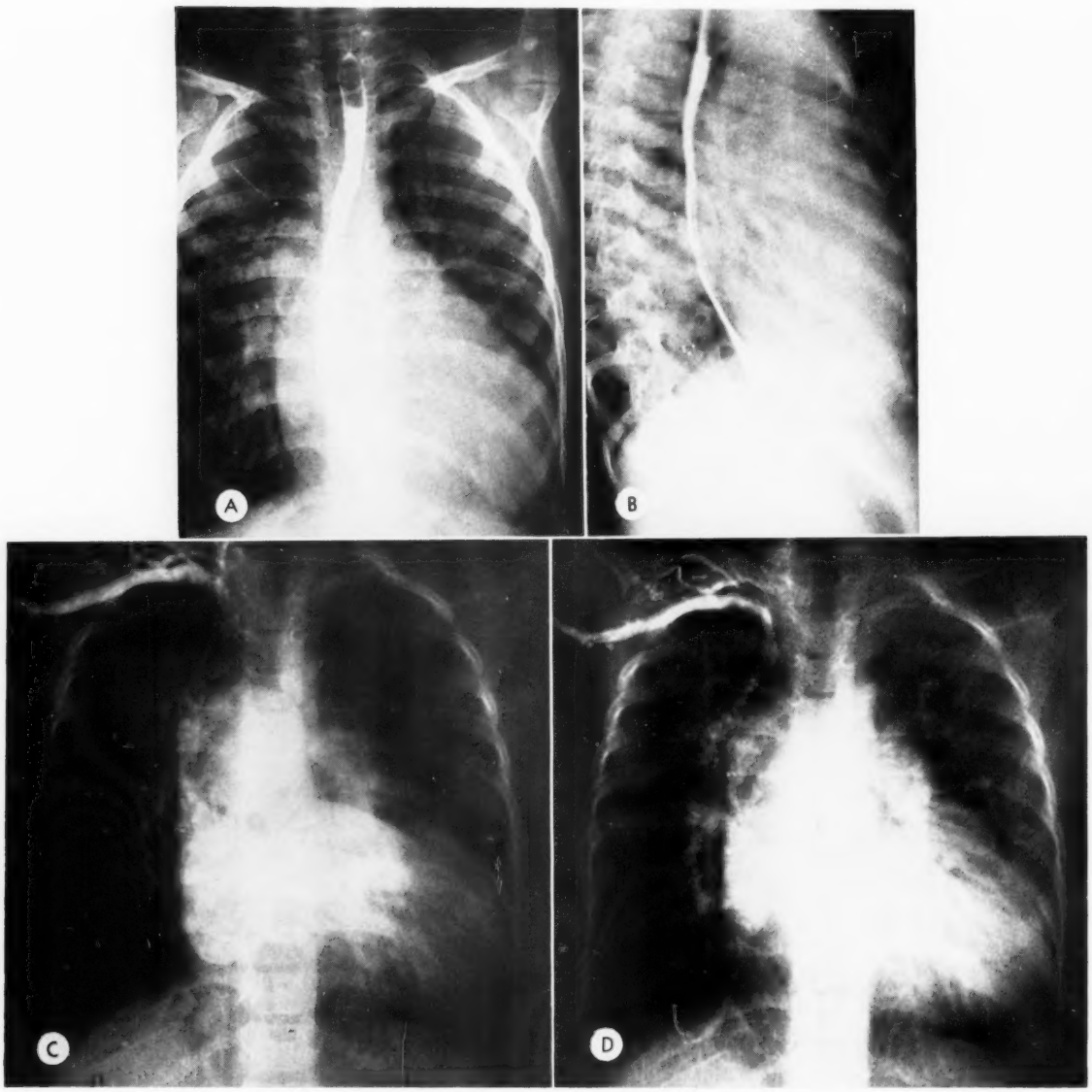

FIG. 5. Congenitally corrected transposition with ventricular septal defect in a five year old male. (*A* and *B*) Concave upper left border of heart despite left to right shunt. Indentation of esophagus by medially placed pulmonary artery. (*C* and *D*) Angiocardiograms showing medially placed dilated pulmonary artery and laterally placed ascending aorta.

corrected transposition.[1] In general, the physical examination is of little value in making this diagnosis, since the dominant findings are those due to the associated anomalies. In patients with pulmonary stenosis, the second heart sound in the second left interspace is louder than would be expected. This is consistent with the anomalous position of the great vessels. The "second pulmonic sound" heard in these patients is in fact the aortic component of the second sound.

Complete heart block is associated with congenitally corrected transposition in 10 to 20 per cent of the cases. In addition, first degree atrioventricular block (prolonged PR interval) is frequently associated with this lesion. A fairly consistent

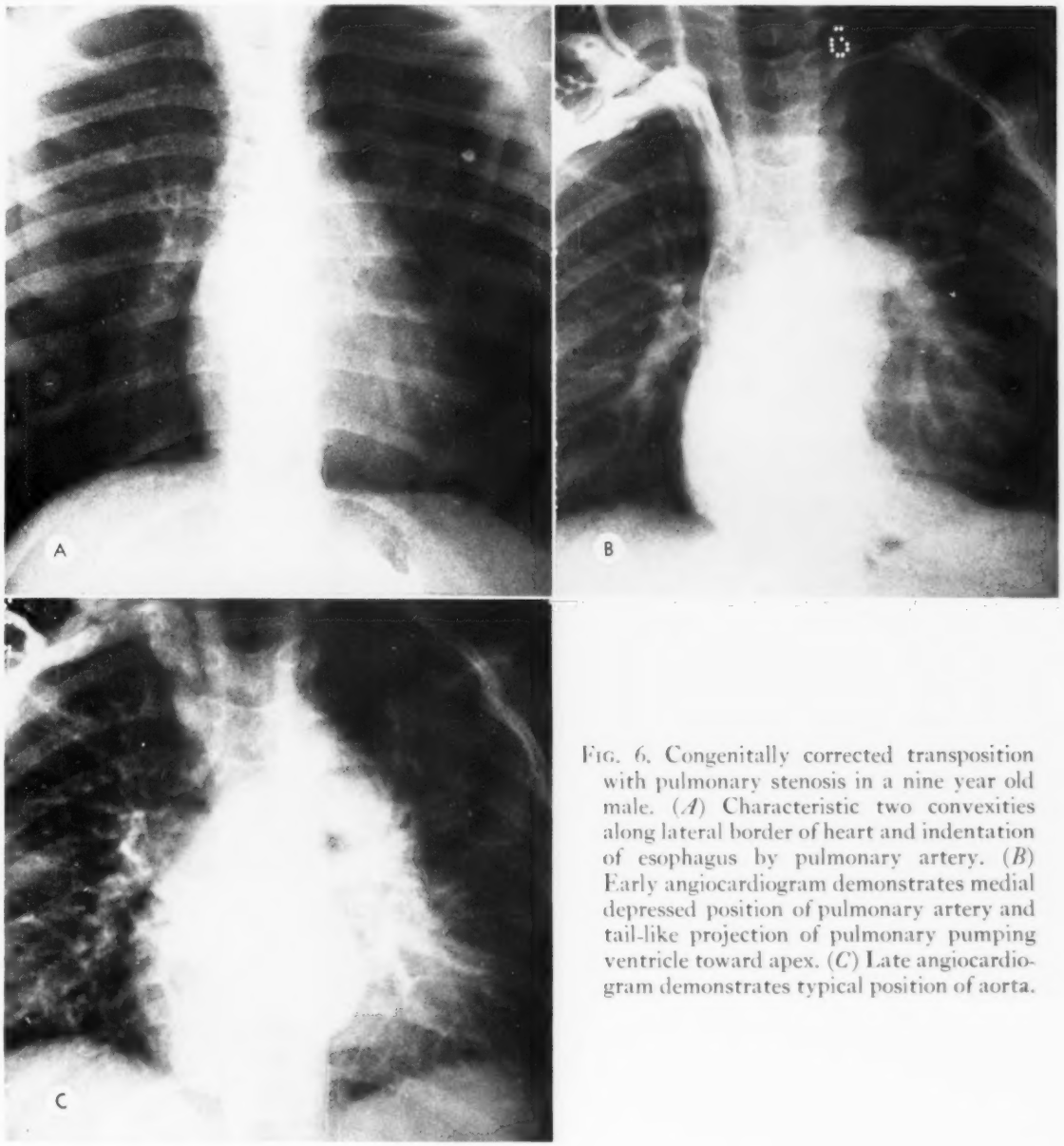

Fig. 6. Congenitally corrected transposition with pulmonary stenosis in a nine year old male. (*A*) Characteristic two convexities along lateral border of heart and indentation of esophagus by pulmonary artery. (*B*) Early angiocardiogram demonstrates medial depressed position of pulmonary artery and tail-like projection of pulmonary pumping ventricle toward apex. (*C*) Late angiocardiogram demonstrates typical position of aorta.

finding in the electrocardiogram is the absence of the q-wave in V6 and its presence in V1 or V_4R.

ROENTGENOLOGIC FINDINGS

For convenience of description the roentgen findings are divided into findings on conventional roentgenograms, findings during cardiac catheterization and findings on angiocardiograms.

Conventional Roentgenograms. The findings on plain roentgenograms are largely the result of the associated anomalies. However, certain changes can be seen that may lead to a tentative diagnosis of this condition.

The upper left border of the cardiac silhouette in the frontal view is made up by the ascending aorta. Consequently, a single gentle convexity is frequently seen in this area in place of the normal double convexity of the aortic arch and the un-

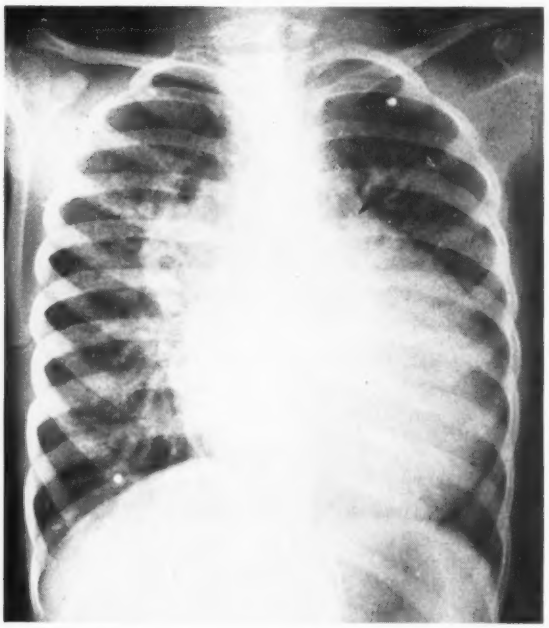

FIG. 7. Congenitally corrected transposition with patent ductus arteriosus in an eight year old female. Arrow points to medially displaced left pulmonary artery.

divided pulmonary artery. The left border of the heart then shows but two convexities instead of the normal three (Fig. 3*A* and 4*A*). In other cases the upper left border of the heart silhouette may be gently concave instead of convex, even in the presence of a left to right shunt (Fig. 5*A*). This depends on the deviation of the ascending aorta as it approaches the arch. The pulmonary artery is medially placed (Fig. 5*B*) and usually, but not invariably, is not a part of the left border of the heart.

Since the pulmonary artery is medially placed and posterior to its normal position, it may cause a distinct impression upon the esophagus below the area of the normal indentation of the arch of the aorta (Fig. 6*A*). In addition, the proximal portion of the left pulmonary artery sometimes can be seen to be medially displaced (Fig. 7).

It must be kept clearly in mind that these signs are not always seen in patients with congenitally corrected transposition. The pulmonary artery, even though medially placed, may not be large enough to indent the esophagus. The thymus may obscure the base of the heart (Fig. 8, *A* and *B*). Finally, if the left pulmonary artery is markedly enlarged, it may give an appearance indistinguishable from that of a dilated undivided pulmonary artery along the left border of the heart (Fig. 9, *A* and *B*).

A review of the roentgenograms of the patients in this series revealed that in 24 cases there were findings suggestive of the diagnosis. However, this film review was performed after the diagnosis had been established, and in a number of these patients congenitally corrected transposition was not mentioned in the initial report.

Cardiac Catheterization. The position of the catheter observed during catheterization may be diagnostic of congenitally corrected transposition, or may suggest a need for angiocardiography for a definitive diagnosis. It should be noted that the evidence for this diagnosis adduced at catheterization is purely roentgenologic and the possible existence of this condition must be borne clearly in mind if appropriate observations are to be made.

If both the pulmonary artery and the aorta can be entered, a definitive diagnosis can be made (Fig. 10, *A*, *B* and *C*). The pulmonary artery is seen medially and posterior to its normal position. The ascending aorta is visualized along the left border of the heart with the arch slightly to the right but the descending portion to the left of the spine.

In cases where the pulmonary artery can be entered but the aorta cannot, the evidence is highly suggestive but not always definitive. The possibility that the catheter may be lying along the medial posterior wall of a dilated pulmonary artery in its usual anatomic position must be considered. Careful manipulation of the catheter around the entire circumference of the pulmonary artery may enable one to make a more definite diagnosis in this situation.

It may be quite difficult to enter the

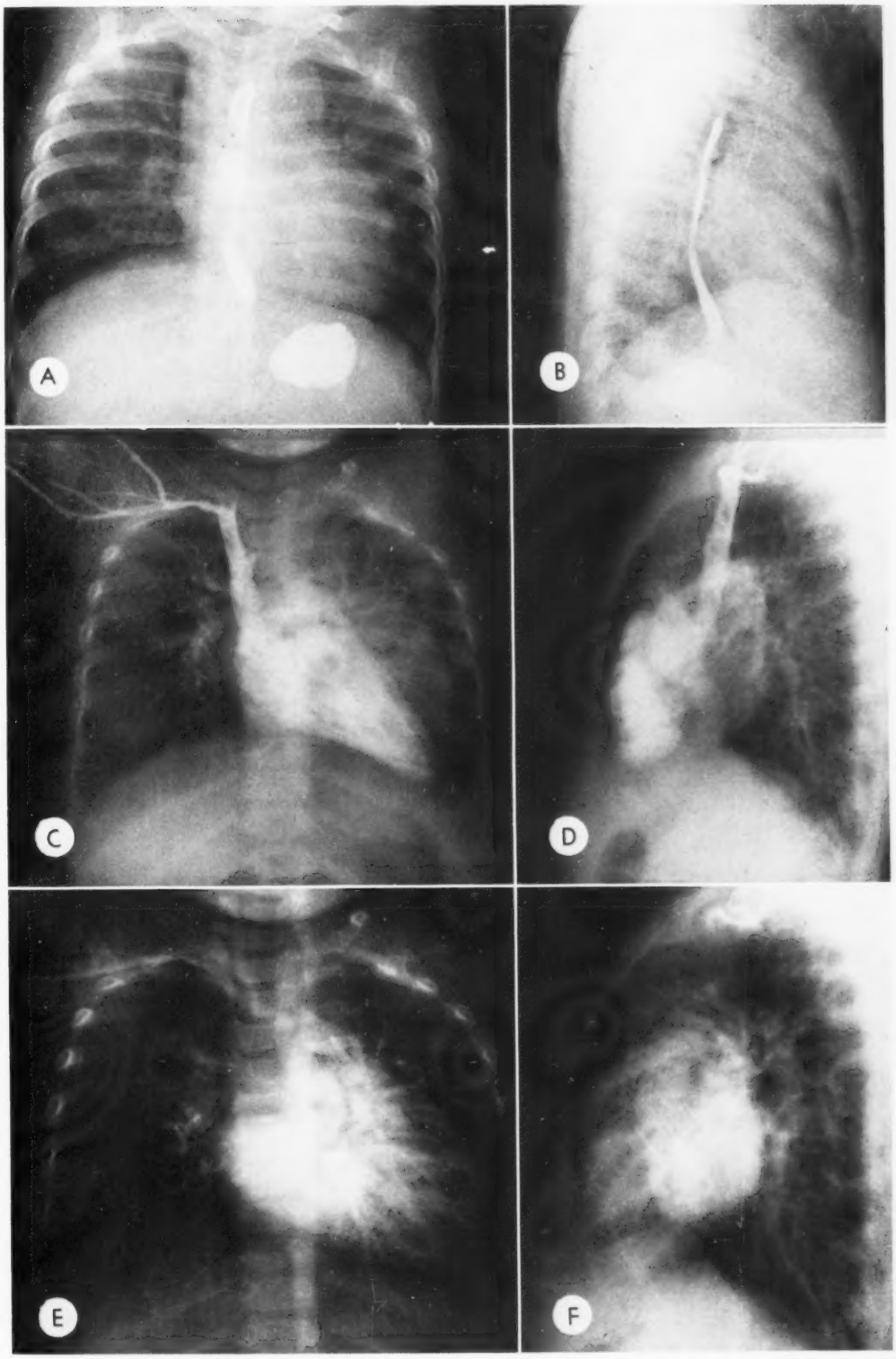

FIG. 8. Congenitally corrected transposition with ventricular septal defect in an eleven month old male. (*A* and *B*) Base of heart obscured by thymus in conventional roentgenograms. (*C*, *D*, *E* and *F*) Angiocardiograms show all of the characteristic features.

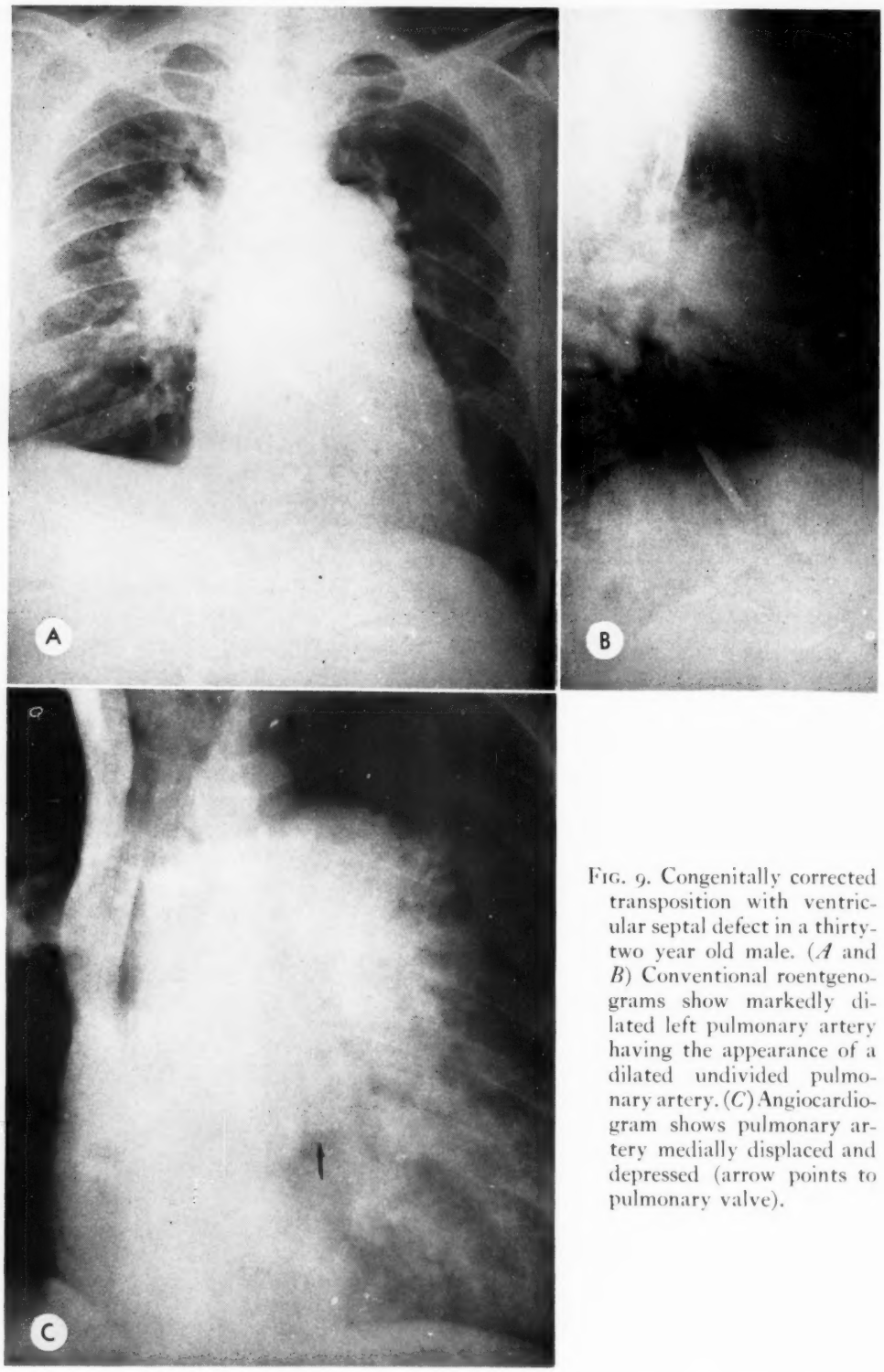

FIG. 9. Congenitally corrected transposition with ventricular septal defect in a thirty-two year old male. (*A* and *B*) Conventional roentgenograms show markedly dilated left pulmonary artery having the appearance of a dilated undivided pulmonary artery. (*C*) Angiocardiogram shows pulmonary artery medially displaced and depressed (arrow points to pulmonary valve).

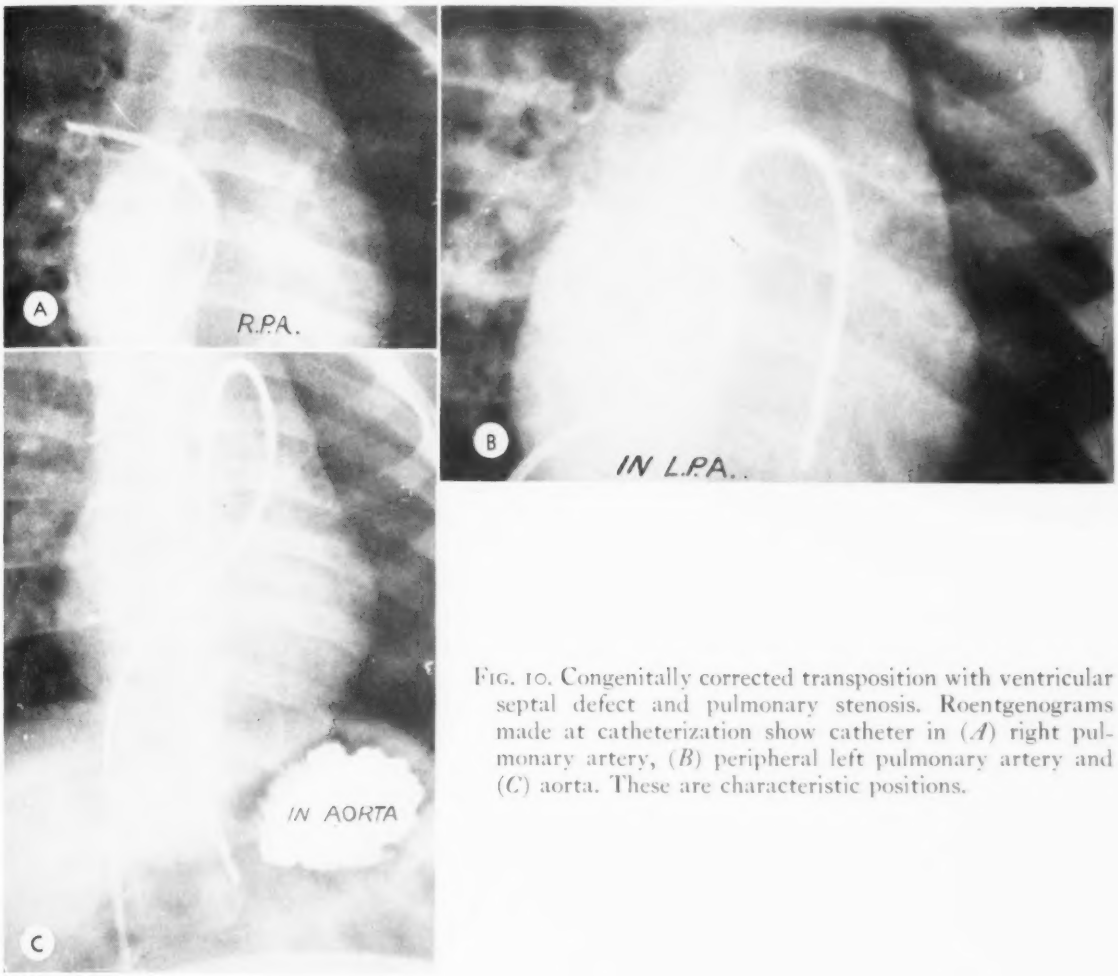

Fig. 10. Congenitally corrected transposition with ventricular septal defect and pulmonary stenosis. Roentgenograms made at catheterization show catheter in (*A*) right pulmonary artery, (*B*) peripheral left pulmonary artery and (*C*) aorta. These are characteristic positions.

pulmonary artery in patients with corrected transposition. Thirty of the 40 patients in this series underwent cardiac catheterization and it was not possible to enter the pulmonary artery in 17. For this reason, it is our practice always to do selective angiocardiography from the ventricle in patients in whom the pulmonary artery is not entered at catheterization.

Angiocardiography. A definitive diagnosis of congenitally corrected transposition is most satisfactorily made by angiocardiography. In most cases, the entire anatomy of the condition can be demonstrated. Although, once again, the appearance is somewhat modified by the other anomalies present, both the pulmonary artery and the aorta can usually be well seen if the examination is performed from the ventricle via a catheter. In addition, the appearance of the pulmonary pumping ventricle and to a lesser extent of the systemic pumping ventricle may be of considerable value in establishing the diagnosis.

In this series, angiocardiograms were obtained in 32 cases. Twenty-nine of these were made in anteroposterior and lateral projections simultaneously utilizing a Schönander biplane film changer. All of these are diagnostic. In one patient a single slight right anterior oblique projection was used. This study too was diagnostic. In 2 patients a single steep left anterior oblique projection was utilized. Although the ascending aorta was seen to

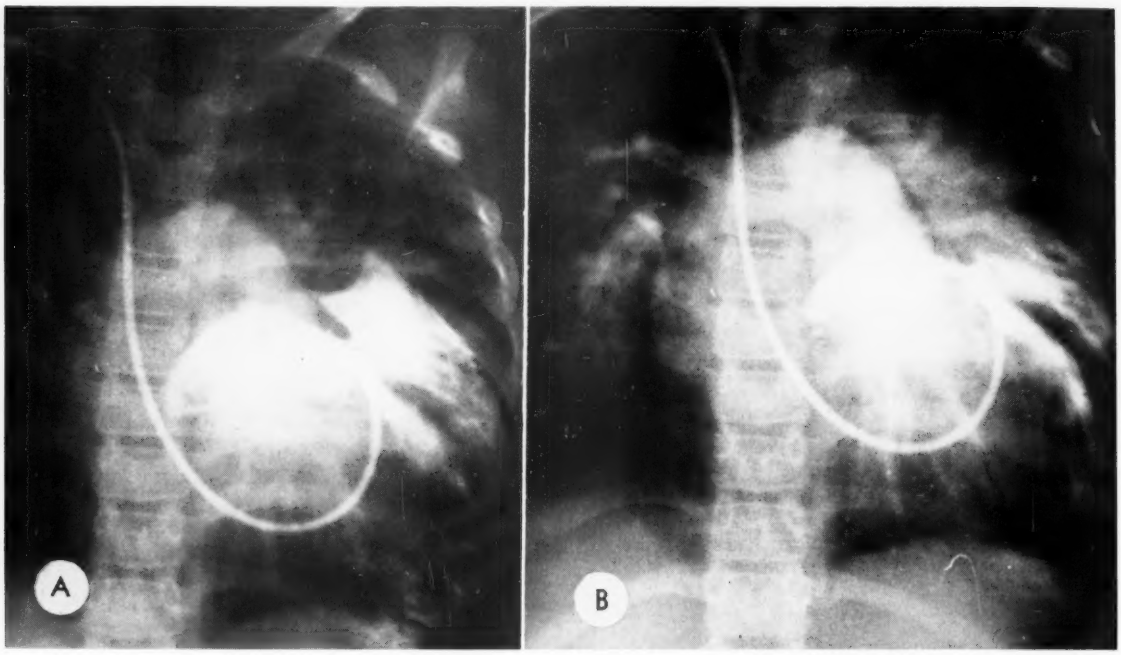

FIG. 11. Congenitally corrected transposition with single ventricle in an eight year old female. (*A* and *B*) Selective angiocardiograms. Tip of catheter at large ventricular septal defect near the small systemic pumping ventricle. Note particularly the position of the great vessels and of their valves.

be somewhat anterior to its normal position and the pulmonary artery posterior, these studies were not considered diagnostic. It is crucial to remember that the most important features are best seen in the frontal plane.

Once again, the position of the undivided pulmonary artery and of the aorta is of utmost value (Fig. 6, *B* and *C*; 8, *C-F*; and 11, *A* and *B*). The pulmonary artery is seen medially and the ascending aorta to the left laterally. The pulmonary valve is depressed and lower than the aortic valve. In the lateral view the posterior displacement of the pulmonary artery and the anterior position of the aorta can be visualized. The plane of the ascending aorta and of the undivided pulmonary artery may appear nearly superimposed.

In the frontal view (Fig. 8*C*) frequently, but not invariably, the pulmonary pumping ventricle presents a tail-like projection toward the apex of the heart with the chamber having an almost triangular shape. It is important to remember that this ventricle is anteriorly placed. The absence of an infundibulum for this ventricle can be appreciated from a study of the angiocardiograms. In consequence, pulmonary stenosis is seen invariably to be of valvular or subvalvular type (Fig. 6*B*). The pulmonary stenosis of tetralogy of Fallot associated with congenitally corrected transposition is also of this type. When not associated with this condition, the stenosis in tetralogy of Fallot is usually infundibular.

Congenitally corrected transposition of the great vessels can also be diagnosed by retrograde aortography in the frontal plane, if the ascending aorta is opacified. Although there are no examples of this in the present series, 2 patients in whom the diagnosis was so established are reported by Thilenius *et al.*[8] This method visualizes the characteristic position of the aorta. It is perhaps a less satisfactory procedure because the position of the pulmonary artery is not thus demonstrated and associated lesions are not shown; however, the an-

omalous position of the coronary arteries can be well demonstrated by this technique.

SUMMARY

Congenitally corrected transposition of the great vessels is a cardiac anomaly in which the pulmonary artery and the aorta are transposed in relation to one another but in which the flow of blood is maintained in the physiologic direction. In this condition there is a concomitant inversion of the ventricular chambers.

A series of 40 patients with this condition has been reviewed with special attention to the roentgenologic features. The associated malformations for each case have been tabulated. The pathologic anatomy of the condition has been described.

The anomaly is of importance because it is much more common than formerly believed, and because of its frequent association with other correctable cardiac defects. Its recognition is of significance to the surgeon in handling the associated anomalies.

The diagnosis of this condition is in large part dependent on the roentgenologic examination. The existence of the abnormality may be suspected on the basis of conventional roentgenograms. The diagnosis is most firmly established by angiocardiography or, in certain cases, by the position of the catheter during cardiac catheterization.

It is hoped that an awareness of this condition will lead to its more frequent demonstration as an isolated anomaly. Whether this condition is in fact benign of itself must depend on future observations of groups of patients with this anomaly.

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LOCALIZATION OF BULLETS AND METALLIC FRAGMENTS IN THE CARDIOVASCULAR SYSTEM: ROLE OF ANGIOCARDIOGRAPHY IN 7 CASES*

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ANGIOCARDIOGRAPHY for the localization of bullets in the heart was reported from this center in 1950 and 1951.[7,8] Goyette and Keirns[12] in 1951 reported 2 cases with metallic fragments in the heart in Korean veterans. In one, angiocardiography showed the metal to be embedded in the ventricular septum. In the other, the fragment was revealed to be within the right ventricle. Swan and associates[23] reported the same 2 cases and stressed the surgical indications and aspects of removal of foreign bodies in the heart.

Seven patients with metallic bodies in the cardiovascular system have been studied angiocardiographically and form the basis of this report. Practically all the clinical features emphasized in the literature,[6,11,12,15,16,17,20,23,24] including the tendency of foreign bodies to become embolic,[6,15,16,17,20,22] were encountered in this series. Two of the patients had successful removal of bullets; one from the right ventricle, the other from the right atrial appendage. Four patients were asymptomatic and in these surgery was not indicated. The remaining patient suffered a right hemiplegia and interventricular block soon after injury; recurrent cerebrovascular seizures made removal of the bullet from the left ventricle hazardous.

REPORT OF CASES

CASE 1. *Bullet at Base of Ventricular Septum for Forty-Three Years.* A fifty-nine year old housewife (N.Y.H. No. 345397) came to the clinic on December 4, 1952, because of burning epigastric pain of six months' duration. At the age of fourteen years, while in Ireland, she had been accidentally shot in the left side of the abdomen. Abdominal laparotomy had failed to locate the bullet; an uneventful recovery had followed. Physical examination revealed only slight epigastric tenderness. The cardiovascular system, including the electrocardiographic study, was normal; the blood pressure was 130/82 mm. Hg. Gastrointestinal roentgen study on December 8, 1942, revealed a deformed duodenal cap and the diagnosis of an active duodenal ulcer was made. On a diet, the patient improved but persistent although slight epigastric tenderness recurred. Repeat roentgenoscopy of the gastrointestinal system on March 18, 1943, revealed a bullet in the lower left hemithorax which moved synchronously with the heart. A roentgenogram of the chest showed the bullet to be at the diaphragmatic surface of the heart (Fig. 1, *A* and *B*). The roentgenogram of the opacified stomach (Fig. 1*C*) shows why contrast studies of the alimentary system may sometimes mask a foreign body.

For the next five years the patient had recurrent attacks of epigastric discomfort necessitating repeated roentgen examinations of the gastrointestinal system. During these, the roentgen study of the heart showed the position of the bullet to be unchanged. On December 7, 1948, angiocardiography was performed for the precise localization of the bullet. Frontal and lateral views showed that a 0.38 mm. caliber bullet was located at the base of the ventricular system on the diaphragmatic surface of the heart (Fig. 1, *D*, *E*, *F*, *G*, *H* and *I*).[7,8] Since the patient was free of cardiovascular complaints and because the bullet had remained fixed in the ventricular septum over the many years of observation, cardiac surgery was considered to be unnecessary. The patient has attended the clinic regularly and has had recurrent attacks of epigastric pain; gastric operation was advised but refused by the patient. The most recent visit on February 13, 1959 was for fracture of the wrist due to falling on ice. Gastrointestinal complaints were not elicited.

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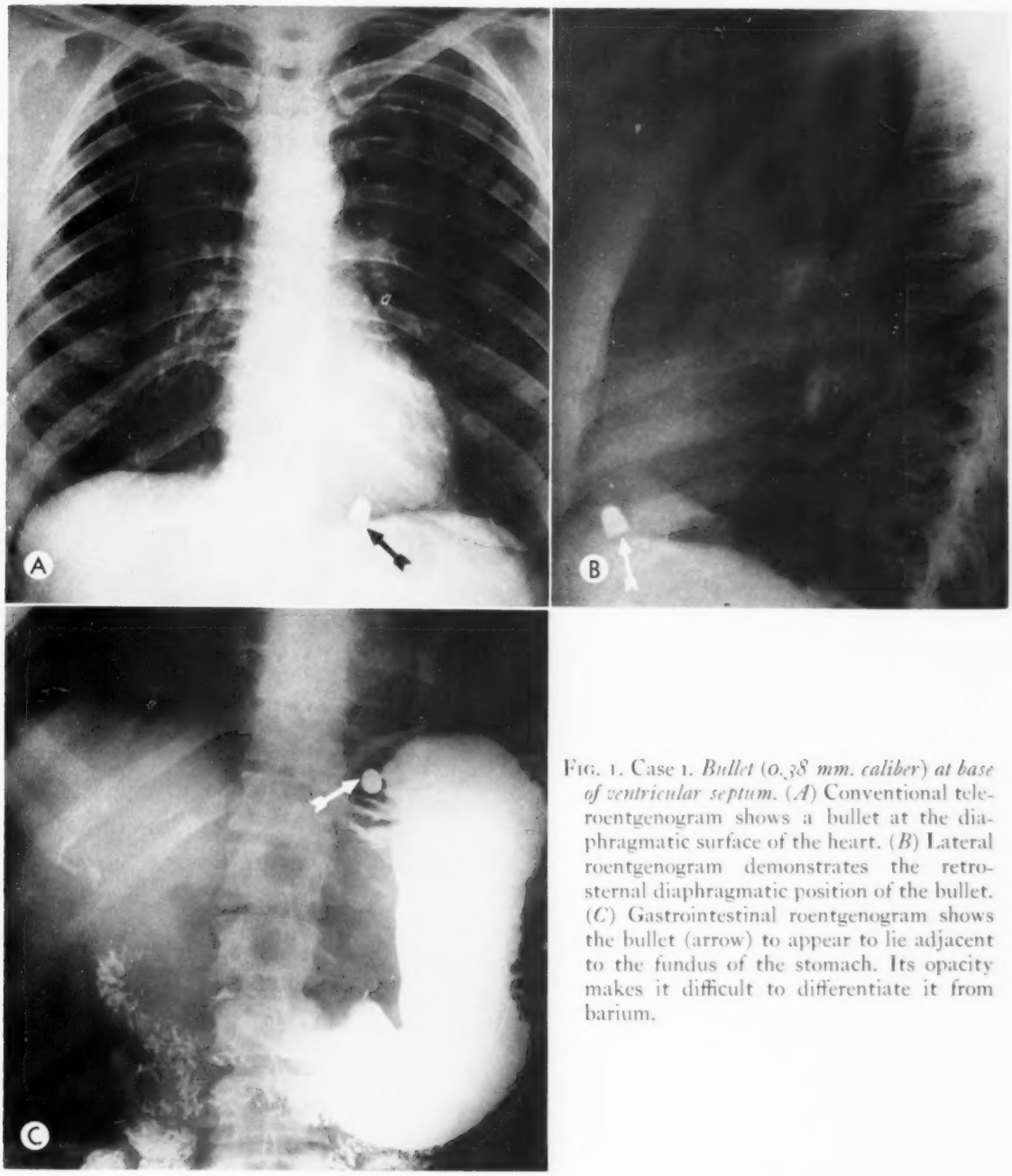

FIG. 1. Case 1. *Bullet (0.38 mm. caliber) at base of ventricular septum.* (*A*) Conventional teleroentgenogram shows a bullet at the diaphragmatic surface of the heart. (*B*) Lateral roentgenogram demonstrates the retrosternal diaphragmatic position of the bullet. (*C*) Gastrointestinal roentgenogram shows the bullet (arrow) to appear to lie adjacent to the fundus of the stomach. Its opacity makes it difficult to differentiate it from barium.

CASE II. *Bullet at Base of Aorta.* A thirty-nine year old ex-pugilist (N.Y.H. No. 574057) was referred for angiocardiography. On May 13, 1950, during a drinking bout, he had been shot in the left chest at close range (two yards) with a 0.22 mm. caliber revolver. He was rushed to a hospital where examination disclosed a 0.5 mm. oval break in the skin at the fifth costosternal junction; there was no point of exit of a bullet. Because of cardiac tamponade (a feeble, rapid pulse, low blood pressure, a poorly pulsating heart which contained a bullet, and an increased venous pressure of 170 mm. water), an exploratory thoracentesis was performed within an hour of admission. At operation, the left pleural cavity was free of blood but the anterior mediastinum was bloody and the pericardial sac contained large quantities of free and clotted blood. A bullet hole, 0.5 mm. in diameter, was seen to extend into the pericardium and right atrium

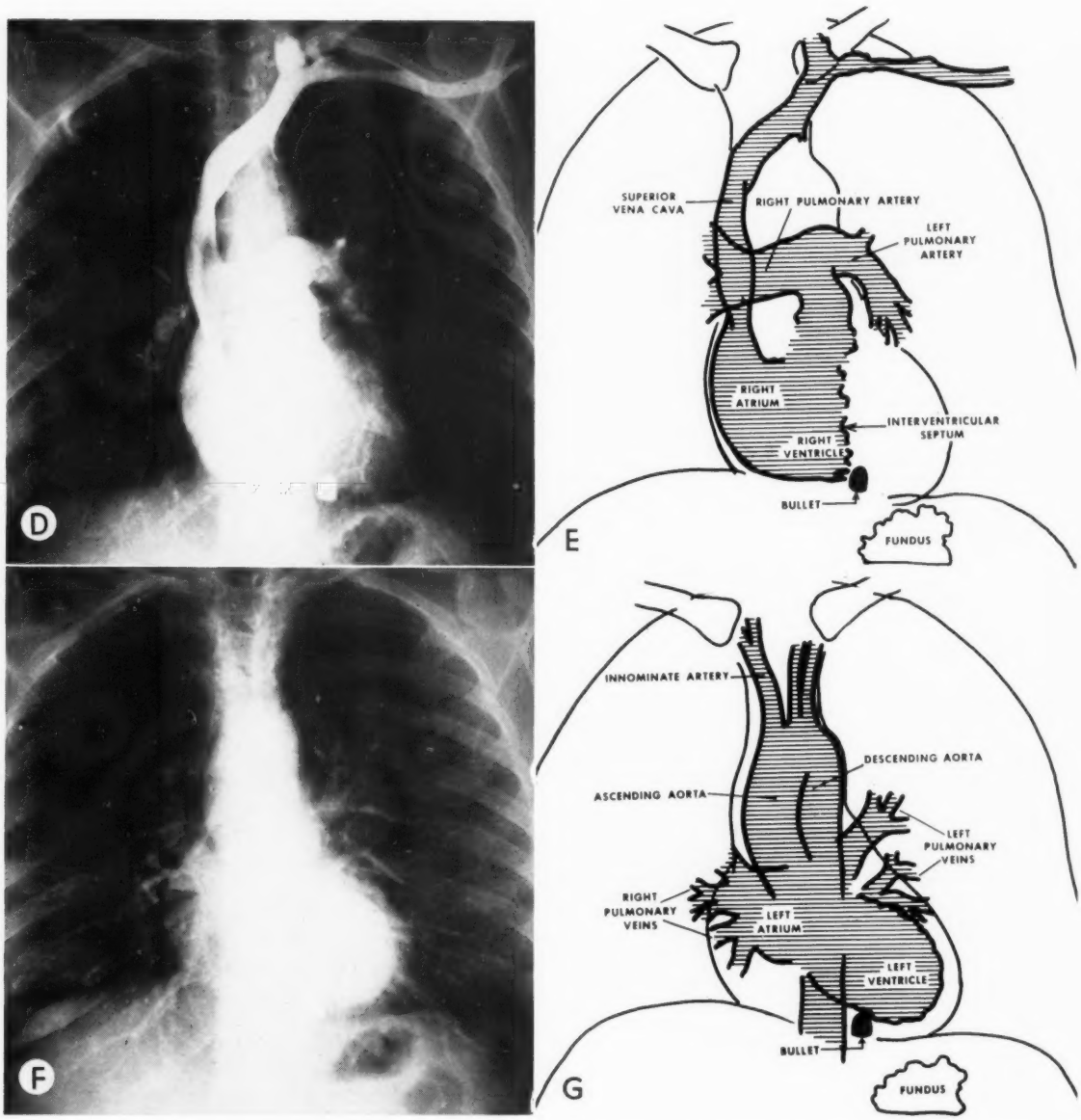

Fig. 1. Case 1. (*D*) Frontal teleangiocardiogram shows the bullet to be below the right heart chambers. (*E*) Tracing of *D*. (*F*) When the left heart is filled, the bullet is adjacent to the ventricular septum. (*G*) Tracing of *F*.

just distal to the atrial appendage. Moderate bleeding at this area resulted when the heart was manipulated; the bullet could not be palpated. The right atrium was sutured, the pericardium was opened widely and after inserting the drainage tube, the chest was closed. The patient made an uneventful recovery and on June 22, 1950, he was referred to this hospital for angiocardiography. This disclosed a freely movable 0.22 mm. bullet to lie at the base of the aorta (Fig. 2, *A* and *B*). Since the patient was asymptomatic and the bullet had not been palpated during operation, further surgery was not attempted. Subsequent examination at the referring hospital (only a month later) showed the patient to be well, the bullet remaining in the same site.

Case III. *Bullet Indenting the Undersurface of the Right Pulmonary Artery for Thirty-Two Years.* A fifty-six year old dentist (N.Y.H. No. 587867) was admitted on December 7, 1950, because of chest pain and cough of three months' duration. Examination disclosed enlarged firm

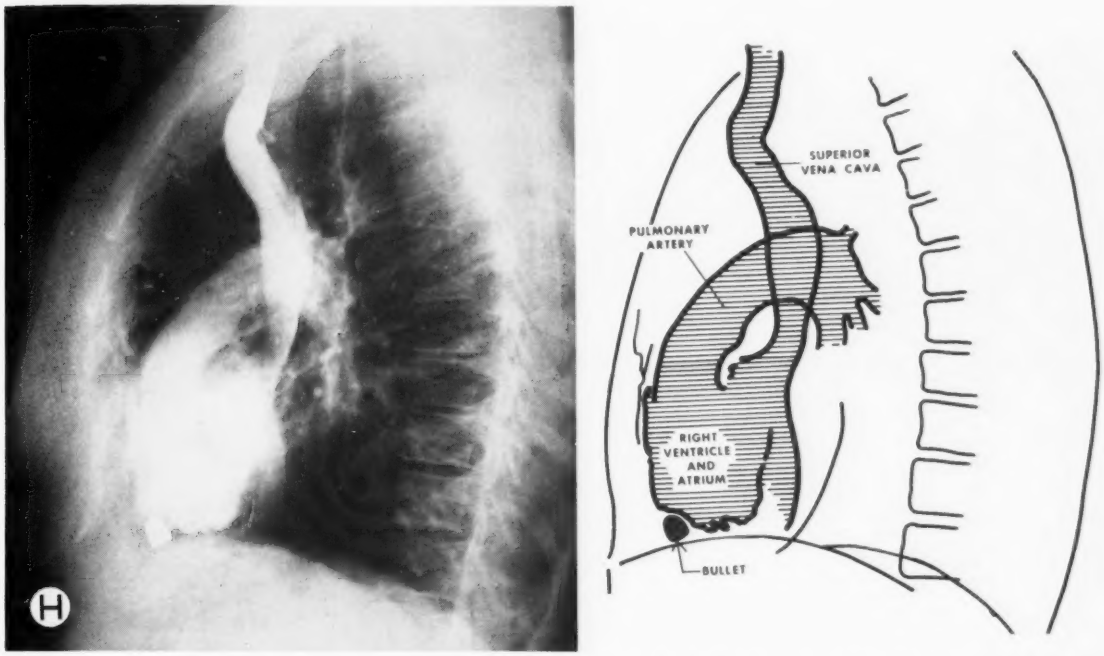

Fig. 1. Case 1. (*H*) The lateral angiocardiogram also shows that the bullet is not within the cardiac chambers. (*I*) Tracing of *H*. (*D* to *I* reproduced with permission of Paul B. Hoeber, Inc.[8])

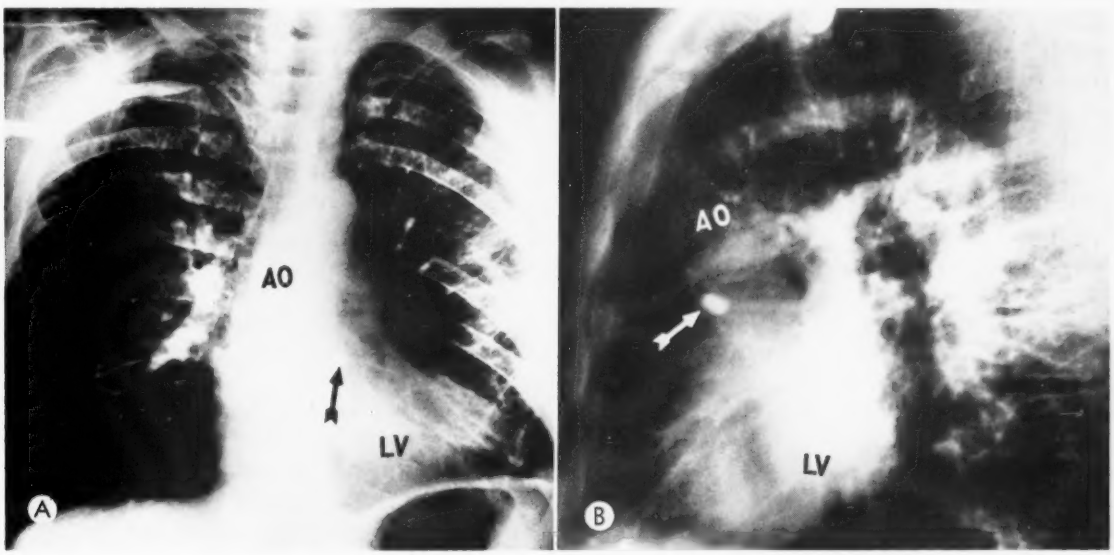

Fig. 2. Case 11. *Bullet (0.22 mm. caliber) at base of aorta.* (*A*) Frontal teleangiocardiogram during left heart opacification reveals the bullet (arrow) to be at the base of the aorta (AO) just below the left sinus of Valsalva. LV is left ventricle. (*B*) Lateral angiocardiogram also shows the bullet (arrow) now located just above the right sinus of Valsalva. LV is the left ventricle; AO, the aorta.

right supraclavicular lymph nodes and a right pleural effusion. During combat in World War I, the patient had been shot in the right shoulder and had also sustained multiple shell fragment injuries to the abdominal wall. Subsequently, after roentgen examination of the chest, he was told that a bullet was lodged near the aorta. Roentgen study during the present admission showed a right pleural effusion, widening of the mediastinum and a 0.38 mm. caliber bullet in the right hemithorax close to the right border of the spine. Angiocardiography on December 7, 1950, disclosed that the bullet indented the undersurface of the right pulmonary artery at the right hilus 3 cm. from its point of origin from the main pulmonary artery. Right pleural effusion and a mass of right paratracheal lymph nodes were also evident (Fig. 3). Biopsy of the right supraclavicular lymph nodes revealed carcinoma, contraindicating excision of the lung cancer.

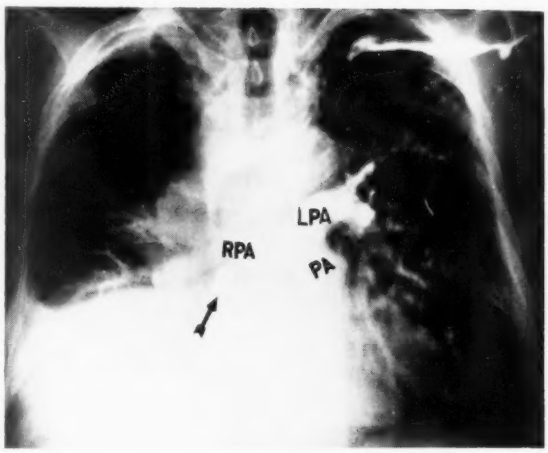

FIG. 3. Case III. *Bullet (0.38 mm. caliber) indenting the undersurface of the right pulmonary artery.* Frontal teleangiocardiogram shows the bullet (arrow) in relation to the undersurface of the right pulmonary artery (RPA). There is a right pleural effusion due to cancer of the right lung. PA is the pulmonary artery and LPA is the left branch of the pulmonary artery.

CASE IV. *Bullet in Right Ventricle, Surgically Removed.* A sixteen year old schoolboy (N.Y.H. No. 591528) previously reported by Leider and Miscall[18] was referred by Dr. Laurence Miscall for angiocardiography for the localization of a bullet in the heart. Three weeks previously (January 4, 1951) the patient had been shot accidentally with a 0.22 mm. caliber rifle bullet which had penetrated the left border of the sternum. Mild shock, a bullet in the heart, and an enlarging cardiac silhouette had indicated cardiac tamponade. Pericardicentesis of 200 cc. dark blood had resulted in considerable clinical improvement. However, two days later, fever, rapid pulse and low blood pressure had developed, necessitating exploration of the pericardium and heart. At operation the pericardium had contained a great deal of blood. A sealed 6 mm. wound of the right ventricle was seen but despite diligent search the bullet could not be found.

After an uneventful recovery angiocardiography was done on January 25, 1951. Preliminary roentgen studies showed a 0.22 mm. caliber bullet within the cardiac silhouette in the diaphragmatic portion of the heart close to the left border of the spine (Fig. 4, *A* and *B*). The frontal angiocardiogram (Fig. 4*C*) clearly located the bullet within the inflow portion of the right ventricle. On February 2, 1951, twenty-eight days after injury, Drs. Leider and Miscall re-explored the heart and felt the bullet to be freely moving in the right ventricle. The bullet was held between the thumb and forefinger and two hammock silk sutures were directed into the heart in order to stabilize the bullet and to reduce blood loss during the incision of the ventricle. The ventricular wall was then incised, the bullet pressed into view and removed with an Allis forceps. Minimal blood loss (less than 50 cc.) resulted because of tension of the hammock sutures and these were then removed and the heart sutured. The patient was well for eight days but then developed right pulmonary infarction attributed to a mural thrombus of the right ventricle. Following antibiotic and anticoagulant therapy he made an uneventful recovery and has remained well.[18]

CASE V. *Multiple Metallic Fragments in the Thoracic and Cardiovascular System.* A twenty year old marine (N.Y.H. No. 598805) was wounded in combat in Korea on September 3, 1950. He was evacuated to the United States and referred for angiocardiography by his physician at a Navy Hospital (April 24, 1951). He complained of dyspnea on exertion and intermittent chest pain in the region of the sternum. There was a mid-sternal wound. Examination of the heart including the electrocardiogram was normal; the blood pressure was 120/72 mm. Hg. Chest roentgenograms disclosed multiple metallic fragments; one of these was seen to be in the right upper lung field, another was retrosternal. The others were located within the cardiovascular structures (Fig. 5, *A* and *B*). Angio-

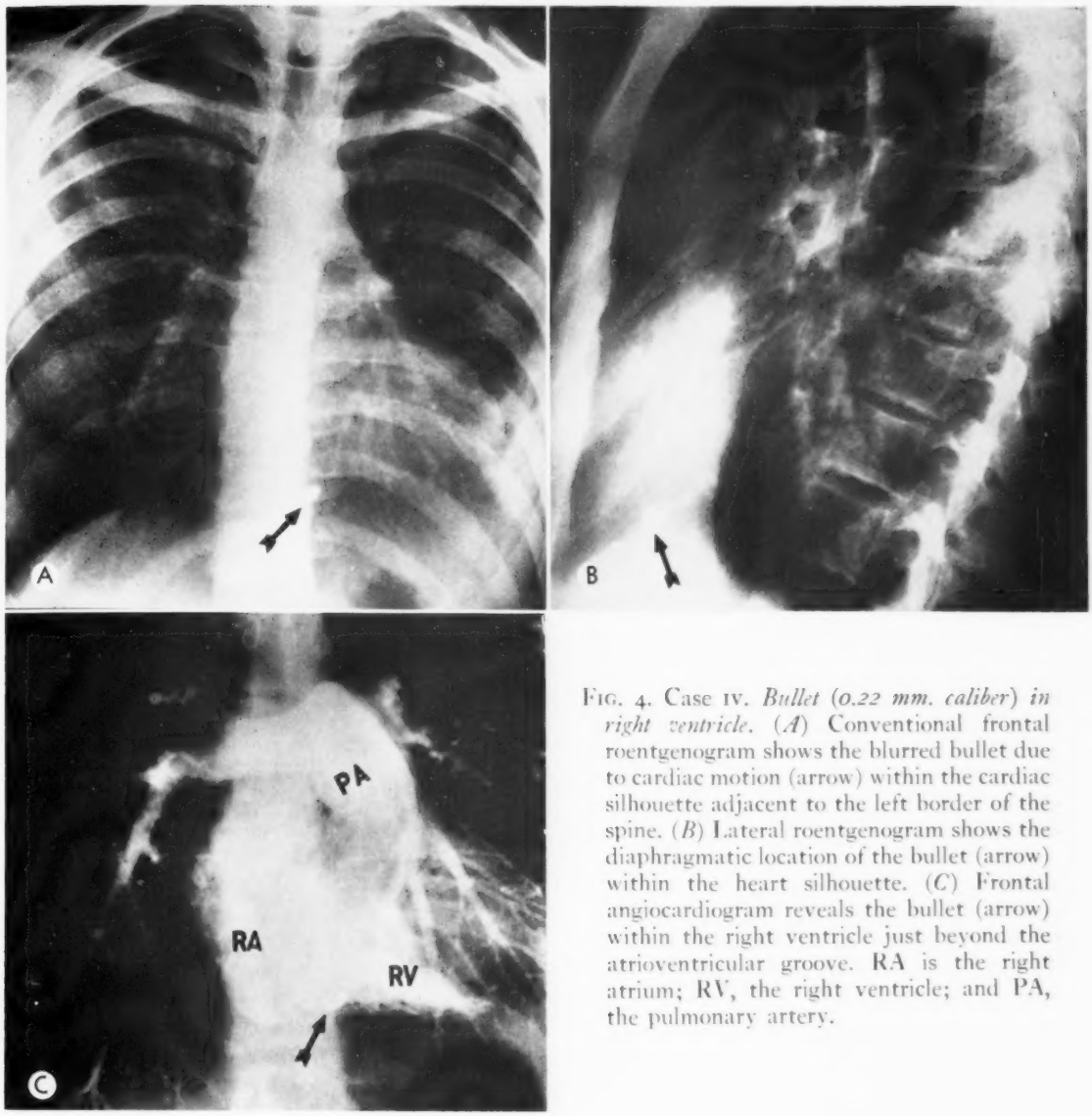

Fig. 4. Case IV. *Bullet (0.22 mm. caliber) in right ventricle.* (*A*) Conventional frontal roentgenogram shows the blurred bullet due to cardiac motion (arrow) within the cardiac silhouette adjacent to the left border of the spine. (*B*) Lateral roentgenogram shows the diaphragmatic location of the bullet (arrow) within the heart silhouette. (*C*) Frontal angiocardiogram reveals the bullet (arrow) within the right ventricle just beyond the atrioventricular groove. RA is the right atrium; RV, the right ventricle; and PA, the pulmonary artery.

cardiography, in frontal and lateral views, revealed one fragment within the right atrial appendage, another within the left atrium near the insertion of the right inferior pulmonary vein (Fig. 5, *C*, *D*, *E* and *F*). Operation was not done because the patient, once he was reassured, became asymptomatic.

Case VI. *Embolic Bullet in the Right Atrial Appendage, Removed Thirteen Years after Leg Injury.* A thirty-six year old Latvian watch repairer was seen in the clinic (N.Y.H. No. 807590) on October 21, 1958, with a chief complaint of "pains in the heart" of twelve years' duration. During combat in World War II in 1946 (he was drafted into the German army), a bullet shattered the left leg just above the knee. The patient was certain that he did not suffer a chest injury. He required several operations of the leg during 1946, and, a year after the leg injury, swelling, pain and inability to freely use the left leg occurred. He then began experiencing attacks of chest pain, which were severe, sharp and located to the left of the sternum but were unrelated to exertion and usually appeared when lying down at night. Eleven years prior to admission after a roentgenographic examination he had been told that he had a bullet in the heart. Subsequently, the chest pains diminished in intensity and frequency. However, a year prior to entry, sharp shooting pain over the left precordium recurred and was associated with a

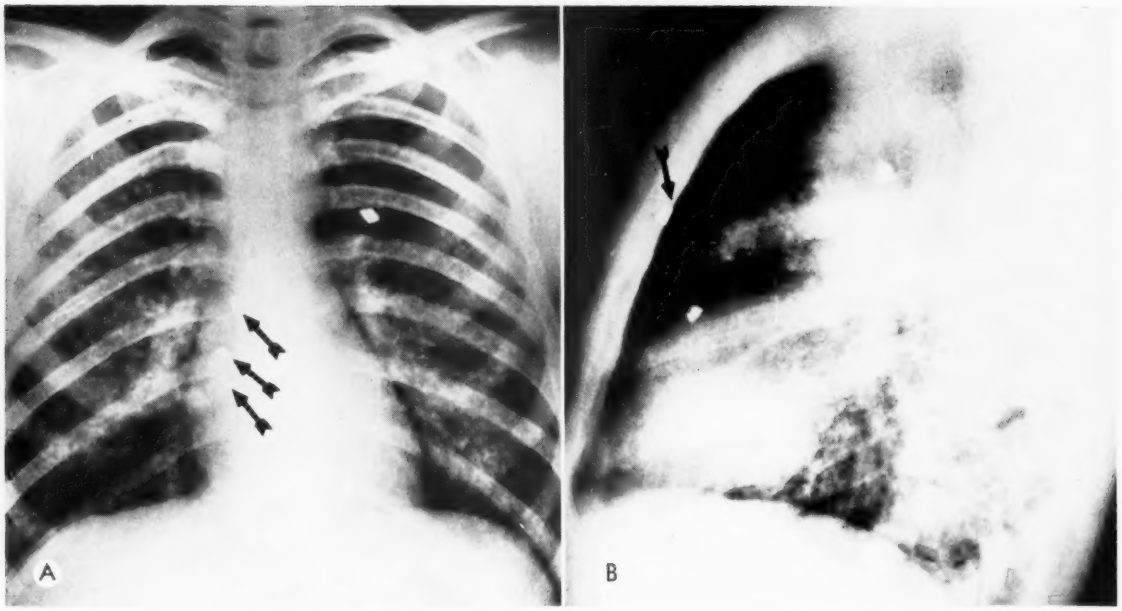

FIG. 5. Case v. *Multiple metallic fragments in the thorax and heart.* (*A*) Teleroentgenogram shows a large quadrangular fragment in the left upper thorax. There are three smaller fragments within the heart silhouette (arrows) to the right side of the vertebral column. (*B*) Lateral roentgenogram demonstrates that one fragment is retrosternal (arrow). The others appear to lie within the cardiovascular structures.

"squeezing, heavy burning sensation." In the past two months, the chest pains increased, causing him to seek medical aid.

The physical examination was normal except for the left leg which was shorter than the right and contained depressed scars over the thigh anteriorly and laterally. The cardiovascular system was normal; the blood pressure was 130/80 mm. Hg. The electrocardiogram was also normal. Roentgen examination of the left thigh (Fig. 6*A*) revealed an old healed fracture of the middle portion of the femur with firm bony union and slight lateral and anterior angulation of the distal fragments. Posterior and lateral to the healed fracture numerous metallic fragments were seen. The roentgen examination of the chest (Fig. 6, *B* and *C*) showed a 9 by 5 mm. bullet in the region of the right atrial appendage.

Angiocardiography was done on November 18, 1958 and clearly showed the bullet to be at the base of the right atrial appendage (Fig. 6, *D* and *E*). On December 4, 1958, a right thoracotomy was performed by Dr. Frank Glenn. The heart was palpated and a 0.22 mm. caliber bullet was felt at the base of the right atrial appendage. A Pott's clamp was placed below the foreign body on the wall of the atrium. An incision was then made over the trapped foreign body and when it was exposed it was extracted by a "stone grasping" forceps. The clamp was then removed and the atrial appendage was sutured. Recovery was uneventful and the patient was discharged nine days after operation. When last seen in the clinic on February 26, 1959, he no longer complained of chest pain.

CASE VII. *Bullet in Posterior Wall of Left Ventricle of Fifteen Years' Duration.* A forty-three year old clerk was admitted to St. Francis Hospital, Roslyn, New York (service of Dr. Edgar P. Mannix, Jr.) on March 9, 1959, with a history of being shot in the left chest during combat in World War II on March 14, 1945. Roentgen examination immediately after injury showed a bullet within the heart. Three weeks after injury, the patient developed a right hemiplegia and had become aphasic. Later at a Veterans Hospital in this country the electrocardiogram showed prolonged conduction time (0.21 to 0.22 seconds). He had been treated with physiotherapy and speech training and had improved. Subsequently, he had regained the use of the right leg although full function of the right upper extremity had never returned. He had gradually overcome the aphasia and had been gainfully employed until 1957 when he sustained a contusion of the head and back following an automobile accident. Since then he has had backache, occasional diplopia, blurring of

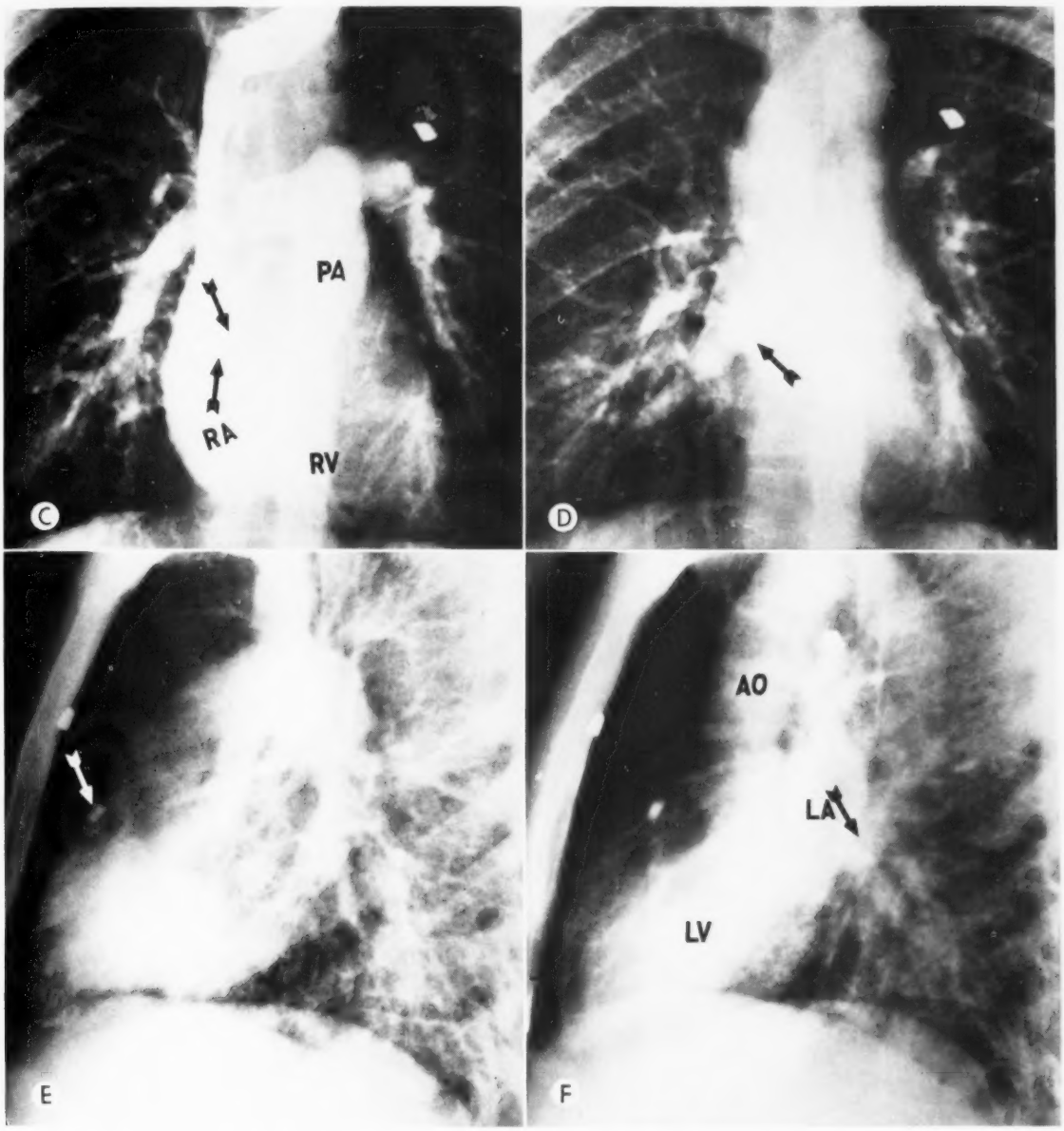

Fig. 5. Case v. (*C*) When the right heart cardiovascular structures are opacified, two fragments in the vicinity of the right atrial appendage are evident (arrows). (Later studies revealed the lower one to be within the left atrium.) RA is the right atrium; RV, the right ventricle; and PA, the pulmonary artery. (*D*) Left heart opacification shows a metallic fragment in the left atrium near the insertion of the right inferior pulmonary vein. The large upper fragment appears to be at the base of the aorta. (Lateral studies, however, showed this to be entirely retrosternal.) (*E*) Lateral right heart angiocardiogram shows the anterior location of a fragment within the right atrial appendage (arrow). (*F*) When the left heart is opacified, the posterior metallic fragment (arrow) lies within the inferior portion of the left atrium. LA is the left atrium; LV, the left ventricle; and AO, the aorta.

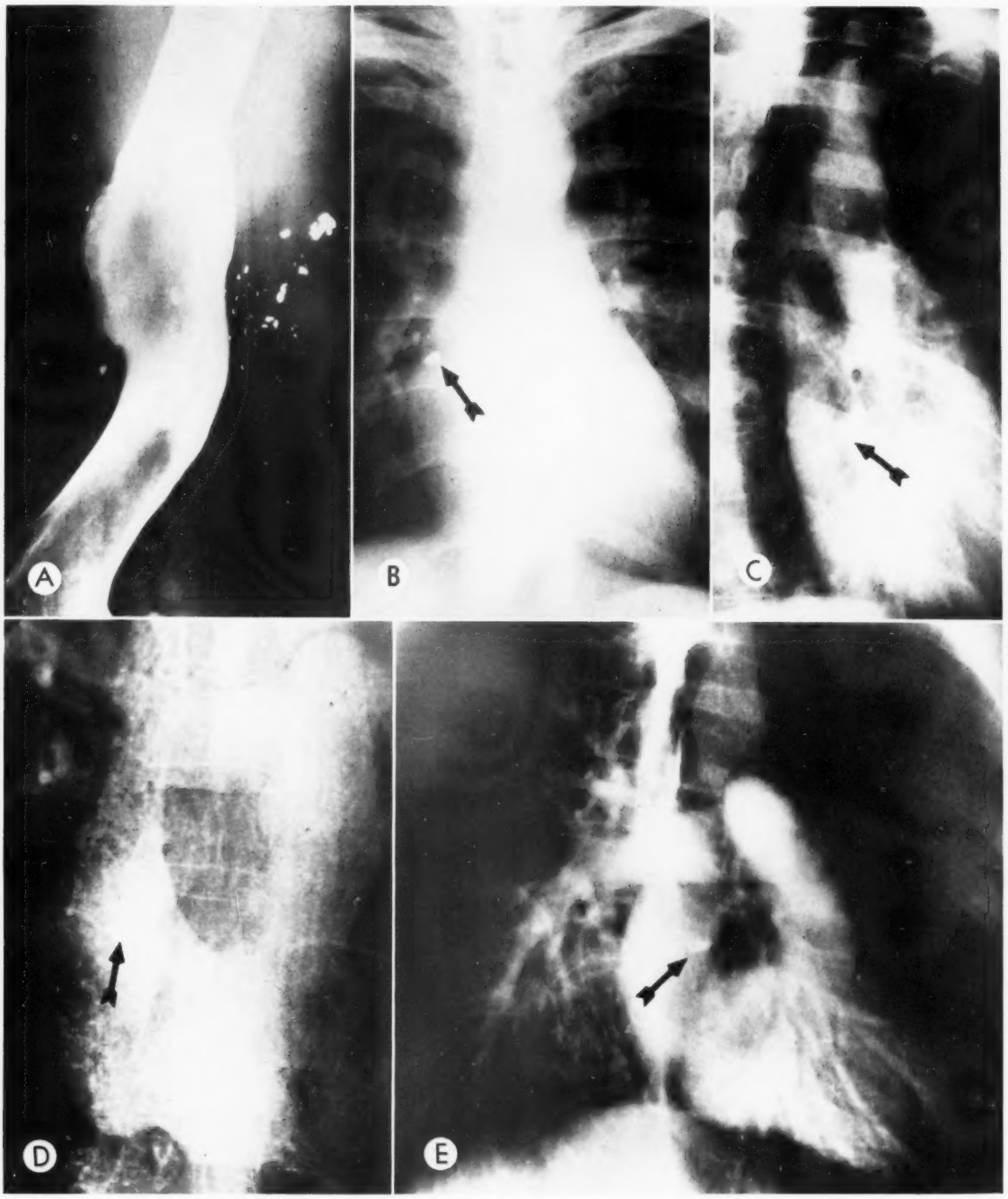

FIG. 6. Case VI. *Bullet (0.22 mm. caliber) within the right atrial appendage.* (*A*) Roentgenogram shows multiple metallic fragments in the left leg with angulation of the femur due to healed fracture. (*B*) Frontal teleroentgenogram reveals a bullet in the upper right cardiac silhouette (arrow). (*C*) Right anterior oblique roentgenogram suggests that the foreign body is within the right atrial appendage (arrow). (*D*) Frontal angiocardiogram (LogEtronic) shows the bullet (arrow) in the upper pole of the right atrium. (*E*) Right anterior oblique angiocardiogram definitely localizes the bullet (arrow) within the right atrial appendage.

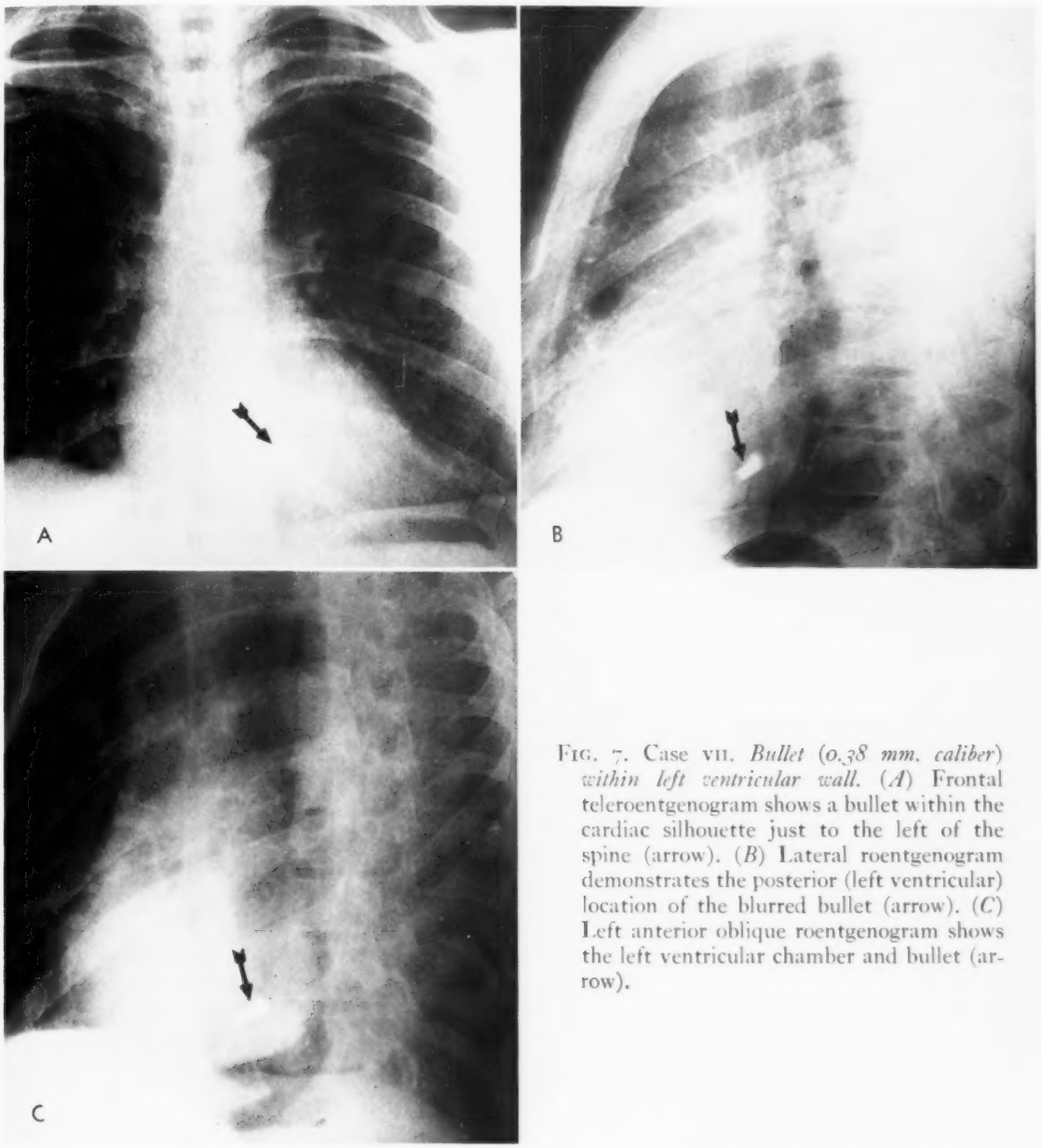

Fig. 7. Case VII. *Bullet (0.38 mm. caliber) within left ventricular wall.* (*A*) Frontal teleroentgenogram shows a bullet within the cardiac silhouette just to the left of the spine (arrow). (*B*) Lateral roentgenogram demonstrates the posterior (left ventricular) location of the blurred bullet (arrow). (*C*) Left anterior oblique roentgenogram shows the left ventricular chamber and bullet (arrow).

vision followed by disorientation, agitation, unreasonable behavior and convulsive seizures of short durations. In addition, the speech began to be slurred and hesitant.

Physical examination showed paralysis of the right upper extremity and partial paralysis of the right lower extremity. The speech was slurred. A soft blowing (Grade 2) systolic murmur was heard in the fourth intercostal space at the left sternal border. The rhythm was regular; the blood pressure was 128/80 mm. Hg. The electrocardiogram still showed mild interventricular block. The electroencephalographic studies revealed cortical dysrhythmia. Roentgen study of the chest showed a 0.38 mm. caliber bullet in the posterior region of the left ventricle (Fig. 7, *A*, *B* and *C*). He was referred for angiocardiography on March 18, 1959, and this revealed the bullet to be in the posterior wall of the left ventricle (Fig. 7, *D* and *E*).

DISCUSSION

Roentgenography has long become established as being essential in the diagnosis and treatment of bullet wounds and shell fragments of the body. Indeed, in modern warfare, portable roentgenographic equipment

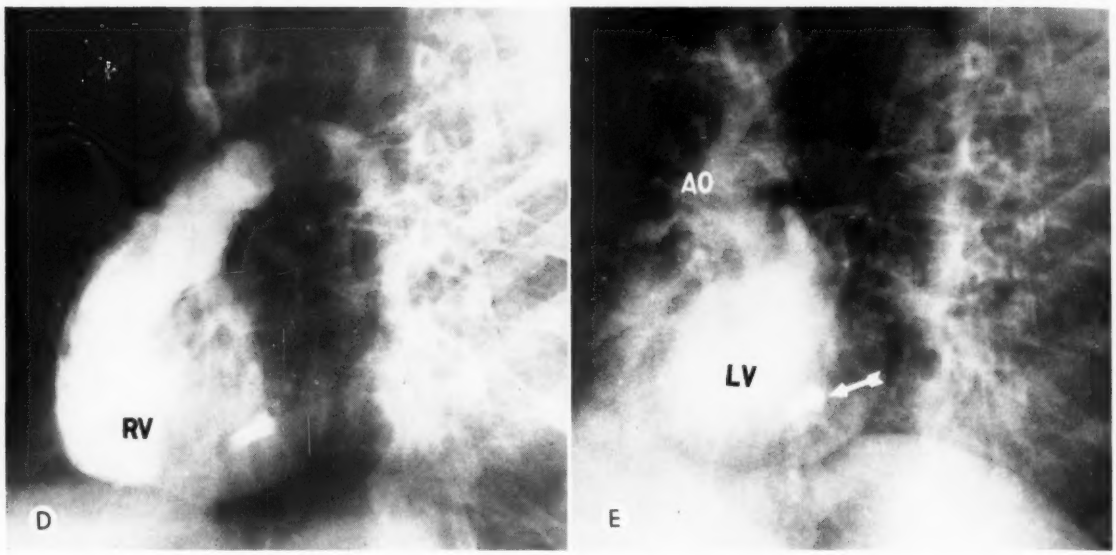

FIG. 7. Case VII. (*D*) Left anterior oblique angiocardiogram shows the bullet to lie well beyond the right cardiac chambers. RV is the right ventricle. (*E*) When the left heart structures are filled, the bullet lies within the left ventricular wall (arrow). LV is the left ventricle; AO, the aorta.

has become a standard requirement for combat zones. In cardiovascular injuries particularly, roentgenography has not only demonstrated metallic objects but has become the most important way to detect the enlarging and poorly pulsating cardiac silhouette (cardiac tamponade) due to pericardial hemorrhage. Of course, other complications such as a fractured rib, hemothorax, pneumothorax and parenchymal disease and injury are also revealed.

Usually, the site of entrance of a bullet or metallic object into the heart is the chest wall, especially the precordium. Occasionally, cardiac injury results from penetrating wounds in the neck, abdomen (Case I) or by embolism from vascular structures Case VI).[6,15,16,17,20,22] Any part of the heart may be injured. The anterior surface, the right atrium and ventricle (Case IV) and the left ventricle (Case VII) are apparently the most common sites. Laceration and perforation of the myocardium of the interpericardial portion of the great vessels often cause cardiac tamponade; prompt paracentesis is life-saving.[1–6,9–24] Infectious materials carried by the bullet may cause suppurative pericarditis and myocardial abscesses.[15,16,17] Structures such as the coronary arteries, interventricular septum and valve cusps may also be injured and cause myocardial infarction, cardiac arrhythmias or valvular insufficiencies. Rarely, a thrombus may develop at the site of injury, and cause a peripheral embolus, especially hemiplegia (Case VII).

Practically all the clinical features produced by foreign bodies in the cardiovascular system were encountered in the 7 cases herein described. In Case I, the abdomen was erroneously explored; the bullet having lodged in the thorax at the diaphragmatic border of the heart. Pericardial tamponade due to hemorrhage was present in Cases II and IV. In both instances the bullets could not be palpated at operation. However, after the bullet was localized by angiocardiography (Case IV, Fig. 4*C*), it was successfully removed. In 2 patients (Case I and III) the bullets had been present for many years without ill effect. In another patient (Case VI) a bullet was removed from the right atrium, although it had been present in the heart for over thirteen years. In that case, cardiac symptoms, perhaps functional, were probably related to the patient's knowledge that he harbored a foreign body in one of the citadels of his well being.[24] One

patient with multiple small metallic fragments in the thorax and heart (Case v) became asymptomatic after reassurance.

Conventional roentgenography while essential from the beginning of cardiac injury cannot accurately localize foreign bodies in the cardiovascular system. For instance, in Case 1, while a bullet was seen to lie at the diaphragmatic portion of the heart (Fig. 1, *A*, *B* and *C*), cardiac chamber visualization was necessary to pinpoint its localization in the ventricular septum (Fig. 1, *D*, *E*, *F*, *G*, *H* and *I*). A bullet at the base of the aorta (Case II) was not palpated during operation and required angiocardiography to demonstrate that it was at the base of the aorta and freely movable (Fig. 2, *A* and *B*). Localization of a bullet at the undersurface of the right pulmonary artery (Fig. 3), although of academic interest in another case, could only have been achieved by angiocardiography. Location of the bullet in Case v (Fig. 5*C*) in the inflow portion of the right ventricle was, however, of practical importance in the surgeon's decision to remove it.[18] Although conventional roentgenography fairly well localized the bullet in the right atrial appendage in another case (Fig. 6, *A*, *B* and *C*), angiocardiography (Fig. 6, *D* and *E*) confirmed it and accurately predicted that removal should be easy; and so it proved. On the other hand, the deeply situated bullet in the left ventricle (Case VII, Fig. 7, *D* and *E*) indicated that removal might prove hazardous. These data with the intracardiac block and the cerebral complications that followed soon after being shot were determining factors against surgery.

Swan *et al.*[23] have thoroughly reviewed the value of angiocardiography for the localization and indication for removal of intracardiac foreign bodies. They emphasize that advances in anesthesia, transfusion, antibiotics and surgical techniques have made the risks slight. No deaths were reported in the elective surgery for removal of foreign bodies in many recent cases culled from the literature. They also point out that cardiac foreign bodies behave differently, depending upon their exact location within the heart. For instance, foreign bodies free in a chamber have a strong tendency to embolism, whereas those em bedded in the myocardium and not infected will often become enmeshed in a fibrous capsule and become innocuous. Foreign bodies that impinge on myocardium or valve leaflets tend to cause erosion and favor bacterial endocarditis and myocardial disease. Even in the absence of sepsis, these should be removed for prophylactic reasons. Large, jagged bullets and metallic fragments are also more liable to carry in contaminated materials and serve as a nidus for sepsis and cardiac erosion. Small foreign bodies, however, rarely cause infection and constitute contraindications for operation. Asymptomatic patients in whom the foreign body lies entirely within the myocardium also need not have surgery. Operation in such patients is indicated only if there is an intractable cardiac neurosis.

Nonoperative management of cardiac wounds has recently been re-emphasized.[4] Apparently, pericardicentesis, transfusion and the vasoconstrictive drug (norepinephrine) for the treatment of pericardial tamponade and shock have proved more successful than operation soon after injury.[19] Conservative treatment is recommended and preferred and has proved to be specific in many instances.[3,21] In any event, it has also been found to be the best preparatory measure if emergency thoracotomy is required.

SUMMARY AND CONCLUSIONS

Angiocardiography accurately and admirably serves to locate bullets and metallic bodies in the cardiovascular system. In 4 of 7 reported cases, the patients were asymptomatic. Angiocardiography demonstrated that the bullets were embedded in innocuous parts of the heart (the base of the ventricular septum and undersurface of the right pulmonary artery) in 2 cases. In 2 others, although the fragments appeared to be freely movable (aorta, right atrium and pulmonary veins), the small size of the

fragments made removal undesirable. One patient with a large bullet in the left ventricle and with cerebrovascular and cardiac complications was refused operation because the initial injury caused by the bullet was believed to be responsible for progressive disability. Finally, angiocardiography established that bullets were free in the right atrial appendage in one patient and in the inflow tract of the right ventricle in another. Removal of the bullets in both instances was curative.

Multiple metallic fragments of the thorax and cardiovascular system were clearly differentiated in one patient. Angiocardiography, in frontal and lateral views, readily revealed the location of the foreign bodies within opacified chambers or great blood vessels and, of course, excluded the fragments adjacent in the chest wall and pulmonary tissues. Because of the small size and multiplicity of the metallic fragments in this case, operation was not indicated. Reassuring the patient promptly relieved the symptoms referable to the heart and prevented a cardiac neurosis.

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TRAUMATIC ANEURYSM OF THE THORACIC AORTA

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TRAUMATIC thoracic aortic aneurysm can be suspected on routine roentgenographic examination on the basis of characteristic findings. This diagnosis can then usually be confirmed by a careful review of the history with clinical and laboratory procedures to exclude other causes of thoracic aneurysm and with angiographic examination.

Study of more than 100 cases of thoracic aortic aneurysm of various types, which have been referred to the Methodist Hospital, Houston, Texas, for evaluation and treatment, has produced 8 verified cases of traumatic aneurysm which are characteristic in appearance and location. Review of past history has, in all cases, indicated the occurrence of severe trauma to the chest and usually to other portions of the body as well. In some instances, at the time of the original injury, head or extremity trauma was of such magnitude that no chest roentgenograms were obtained. The intrathoracic abnormality was detected on examination weeks, months, or even years later.

Review of the roentgenographic literature indicates that very little attention has been directed to this entity.* Several articles in the surgical and medical literature include discussion of the problem of traumatic aneurysm.[6,8,10,11,17,22,23] There is abundant evidence for the characteristic locations of traumatic rupture of the aorta. Strassman,[22] from autopsy material, furnishes authoritative evidence on sites of rupture which is amplified by less extensive studies and case material by other authors.[3,9,12,13,14,18,25] Rupture just beyond the origin of the left subclavian artery is the most common site, with rupture above the aortic cusps and at the level of the diaphragm being more infrequent. Various theoretic concepts have been introduced to explain the frequency of location of the rupture at these levels.

MacDonell's[15] and McDonald and Campbell's[16] ideas concerning the pathogenesis of this entity seem to be substantiated by the various clinical and pathologic observations to a greater degree than others.

Anatomic fixation of the aorta at these sites, with relative freedom of motion of adjacent parts in combination with mechanical factors of a relatively incompressible column of blood transmitting a shearing or tearing force from the flexible to the fixed point at the time of the injury, seems a feasible explanation. That there may occur a partial tear of one or more of the coats of the aortic wall with subsequent necrosis and the development of hematoma and, later, aneurysm also must be a significant factor. An element of dissection also may occur in some patients.

Syphilis and atherosclerosis are preponderant causes for thoracic aneurysm and can readily be excluded in the type of patient under discussion. Other infections, either from within or without the vessels, congenital defects and certain types of degenerative processes may produce aneurysms. The congenital weaknesses have usually been associated with other congenital defects, such as coarctation, and infections with some generalized process, such as subacute bacterial endocarditis, or some obvious extrinsic erosive lesion. The degenerative processes in younger individuals which result in aneurysm formation show evidence of arterial degeneration in other portions of the aorta or great vessels. If these factors are not present and if there is clinical, antecedent historical and roentgenographic evidence of a localized aneurysm in any of the above described locations, traumatic aneurysm should be suspected. The following case reports

* The excellent paper by Steinberg and Evans, AM. J. ROENTGENOL., RAD. THERAPY & NUCLEAR MED., 1958, *80*, 237–247, emphasizes both acute and chronic traumatic aneurysms and was published after the present material had been collected.

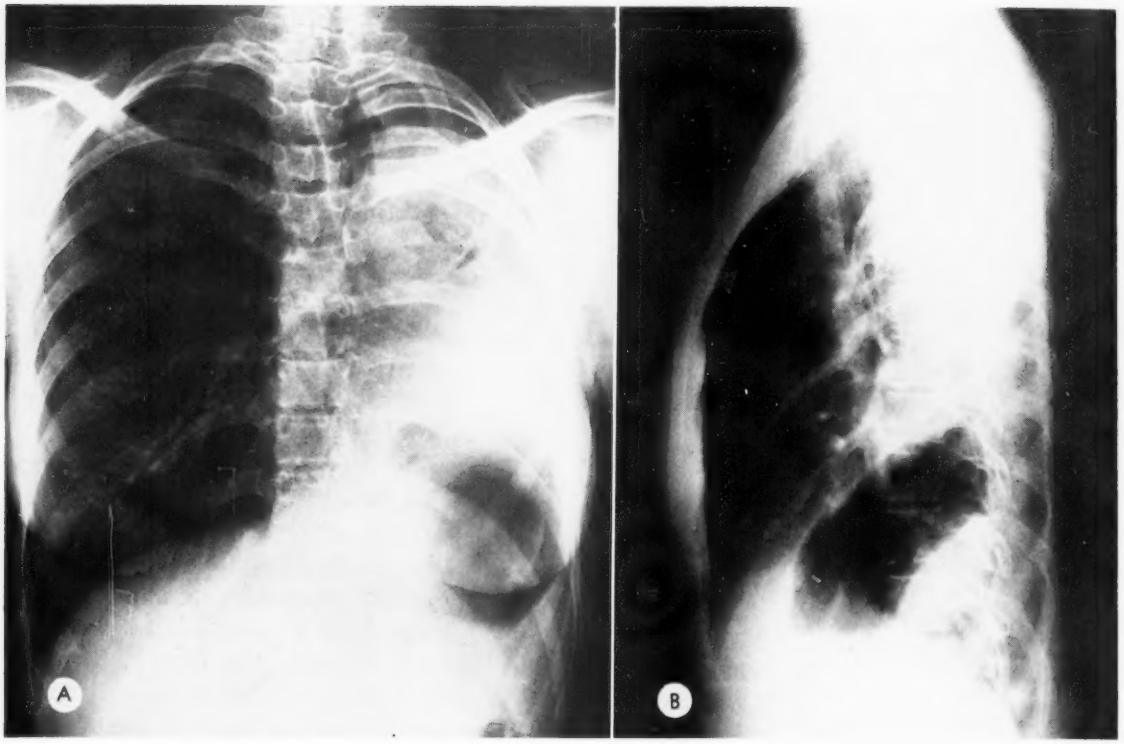

FIG. 1. Case II (M.H., F-28). (*A* and *B*) Routine posteroanterior and lateral roentgenograms demonstrating old left pneumonectomy changes and partially calcified mass in proximal descending aorta. Old thoracic cage fractures are not identifiable.

should serve to illustrate the above contention.

REPORT OF CASES

CASE I.* M. M., male, thirty years old, was admitted to this hospital in 1953 with a diagnosis of traumatic aneurysm of the aorta. Eight years prior to admission, in March, 1945, the patient was in a jeep accident, at which time he was unconscious for six days, sustained a fracture of the jaw and bleeding into the chest; no fractured ribs were noted. Within one month it was believed that the patient had fully recovered; he had been asymptomatic since that time. On a routine chest roentgenogram, a lesion was discovered. Subsequent evaluation showed a partially calcified mass adjacent to the aorta. In July, 1953 this was proved to represent a traumatic aneurysm and was treated by cross-clamping its base, which originated just distal to the left subclavian artery. Pathologic examination showed moderate arteriosclerosis with marked calcific deposition. The patient was discharged from the hospital ten days following operative intervention but was readmitted six months later with recurrence of the aneurysm. At this time, using hypothermia, the aneurysm was resected and a homograft was inserted. The postoperative course was complicated by intrathoracic bleeding which necessitated re-exploration and evacuation of clots but, following this procedure, the patient's course was relatively uneventful and he was discharged three weeks later.

CASE II. M. H., female, twenty-eight years old, was admitted to Methodist Hospital in January, 1955, with a history of having sustained a fracture of the cervical spine and rupture of the aorta during a motorcycle accident in 1946. Fusion of the cervical spine was carried out three weeks after the accident. Because of progressive dyspnea attributed to obstructive emphysema, pneumonectomy was carried out elsewhere in 1949. An obvious traumatic aneurysm was not resected. On admission to Methodist Hospital serology was negative and blood pressure was 114/55. Routine chest roentgenograms showed a partially calcified mass in the left upper hemithorax as well as the postpneumonectomy changes (Fig. 1, *A* and *B*). On January 21, 1956, resection of the aneurysm

* Published previously.[3,4]

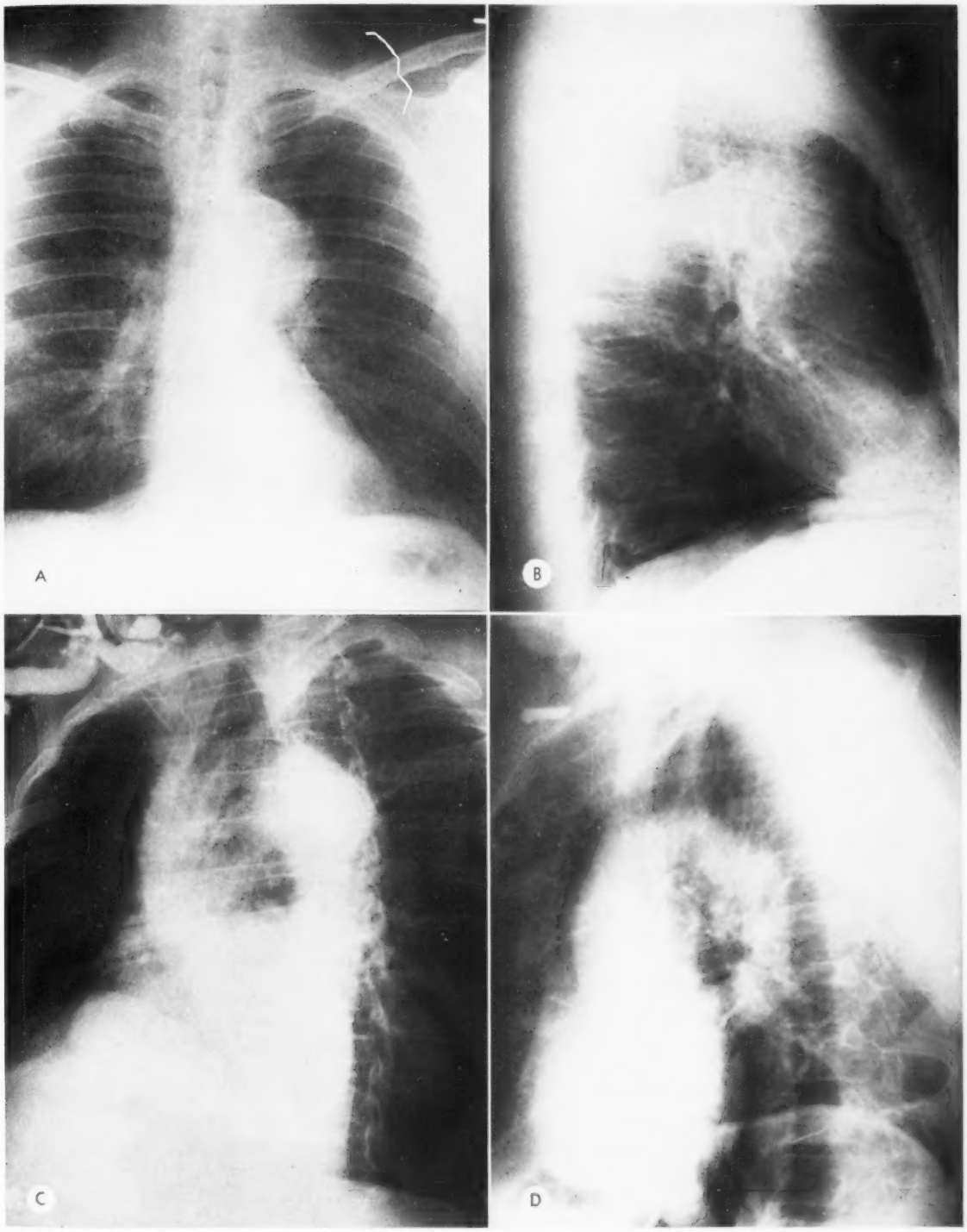

FIG. 2. Case III (S.B.R., M-52). (*A* and *B*) Routine posteroanterior and lateral roentgenograms demonstrating a mass proximal to the descending aorta with calcification in the wall. Old healed rib fractures are identifiable on original roentgenograms. (*C*) Angioaortogram confirms diagnosis of traumatic aneurysm. (*D*) Angioaortogram made twenty-seven months postoperatively.

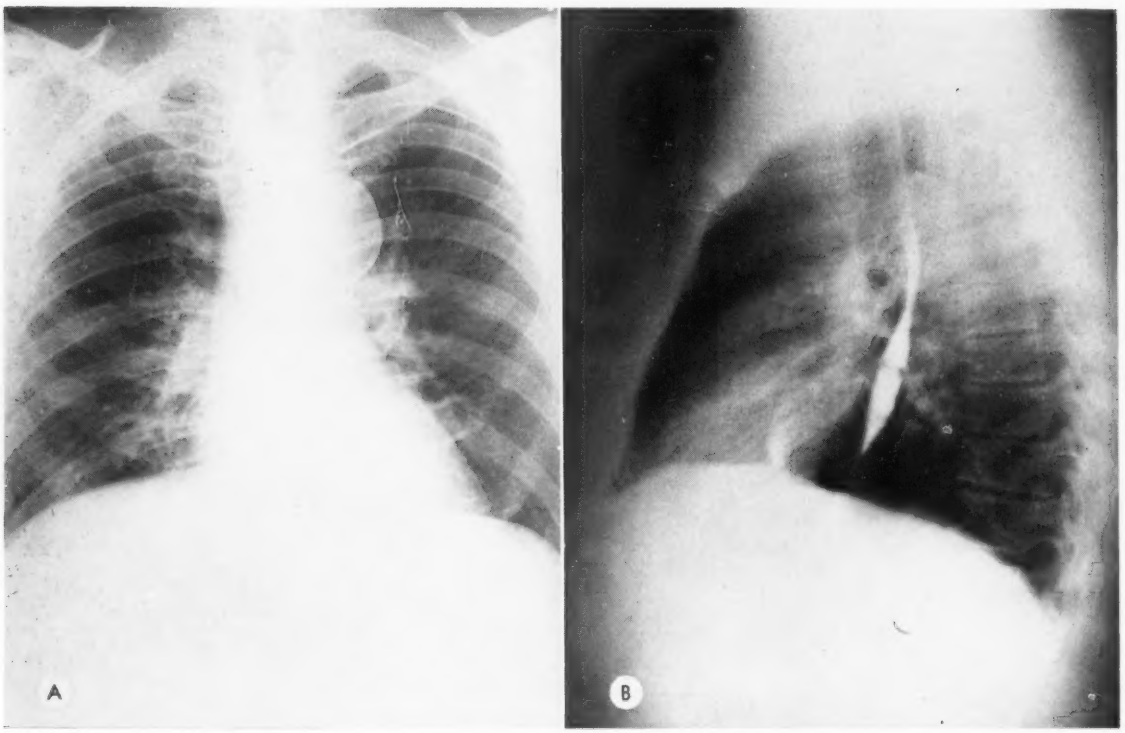

FIG. 3. Case IV (M.L., M-44). (*A* and *B*) Routine posteroanterior and lateral roentgenograms showing mass in proximal descending aorta with characteristic rim of calcification, and old healed right rib and sternal fractures.

with insertion of a homograft was carried out. Massive pulmonary edema developed postoperatively as well as paraplegia. The pulmonary edema was correctable but there was some loss of both sensory and motor function, which persisted. The patient was discharged from the hospital nine days following operative intervention to continue physical therapy on an outpatient basis.

CASE III. S. B. R., male, fifty-two years old, was admitted to Methodist Hospital in February, 1956. A mass had been discovered in the chest on roentgenographic examination which was part of a routine physical examination (Fig. 2, *A* and *B*). There was no history of lues or hypertension. Past history indicated a severe crushing injury to the chest in 1941 during an automobile accident which was said to have "disconnected all the ribs from the breast bone." Serology was negative and there was no hypertension. Angioaortogram showed a saccular aneurysm with some calcification in the wall (Fig. 2*C*). There were multiple healed rib fractures. On February 8, 1956, the lesion was resected and a homograft inserted under hypothermia. The pathologic diagnosis was that of an arteriosclerotic aneurysm. Postoperatively the patient did well and was discharged from the hospital eleven days following operative intervention. In May, 1958, check-up angioaortography was performed showing normal appearance of the operative site and the remainder of the aorta was visualized (Fig. 2*D*). At the time of this check-up examination, no complaints could be elicited.

CASE IV. M. L., male, forty-four years old, was admitted to Methodist Hospital in September, 1956, with a diagnosis of thoracic aneurysm. Nineteen years previously the patient had been involved in an automobile accident which resulted in a depressed sternum and fractured ribs. He recovered from this and a mass thought to be a benign tumor was found incidentally five years later on a routine chest examination. This was observed for a time and then forgotten until the patient was hospitalized for study of hypertension three weeks before admission to this hospital. The mass was rediscovered on routine roentgenographic examination (Fig. 3, *A* and *B*) and angiocardiography showed the true nature of the lesion. On admission, blood pressure was found to be 160/90 and serologic tests for syphilis were nonreactive. On September 26, 1956, the aneurysm was resected using

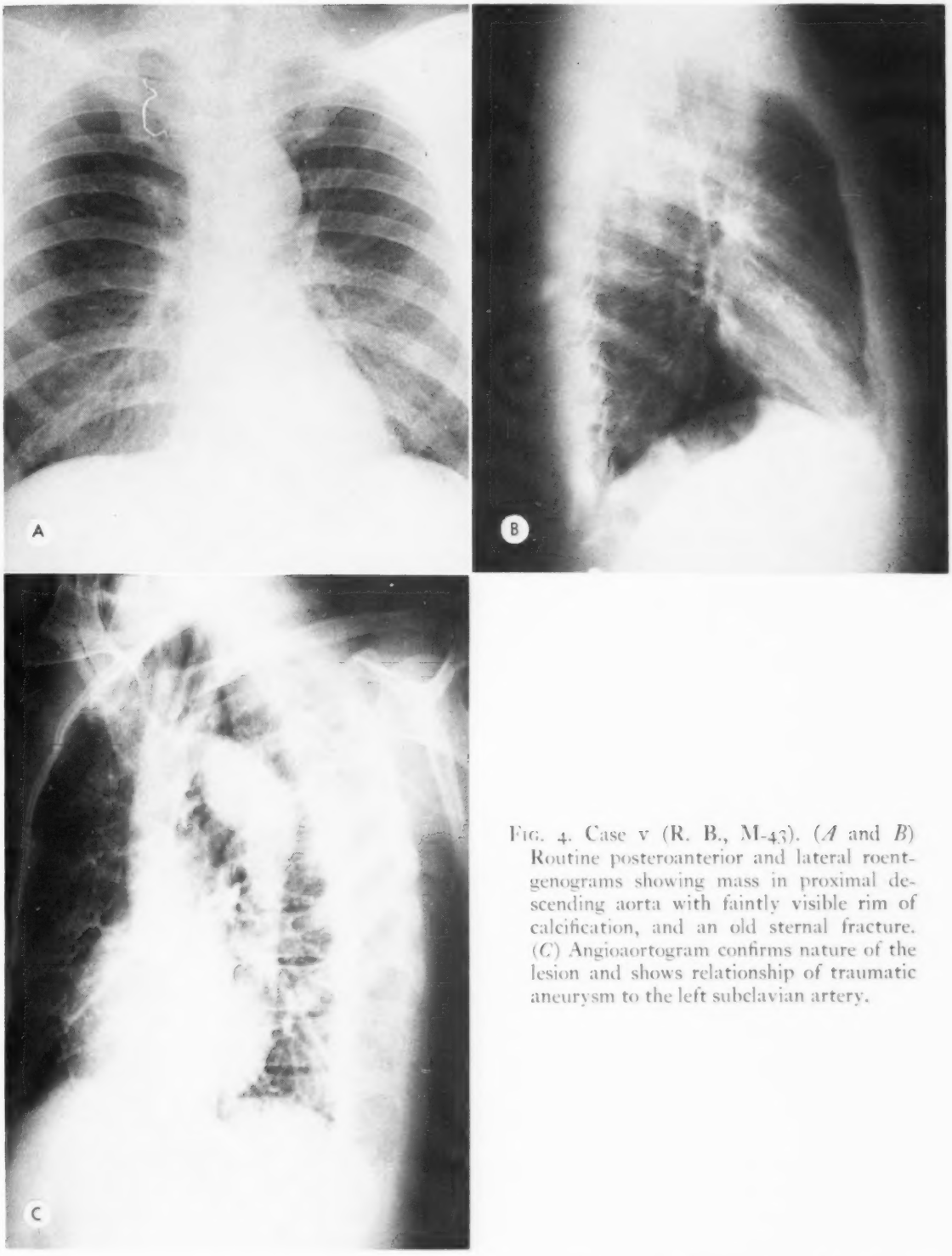

Fig. 4. Case v (R. B., M-43). (*A* and *B*) Routine posteroanterior and lateral roentgenograms showing mass in proximal descending aorta with faintly visible rim of calcification, and an old sternal fracture. (*C*) Angioaortogram confirms nature of the lesion and shows relationship of traumatic aneurysm to the left subclavian artery.

the by-pass pump and a homograft was inserted. The patient's course was complicated by mild cardiac irregularity on the first postoperative day; this was controlled by quinidine. Transient hoarseness was also present associated with trauma to the recurrent laryngeal nerve. The resected specimen showed arteriosclerosis and aneurysm formation. The patient was discharged from the hospital ten days following the operative procedure.

Case v. R. B., male, forty-three years old,

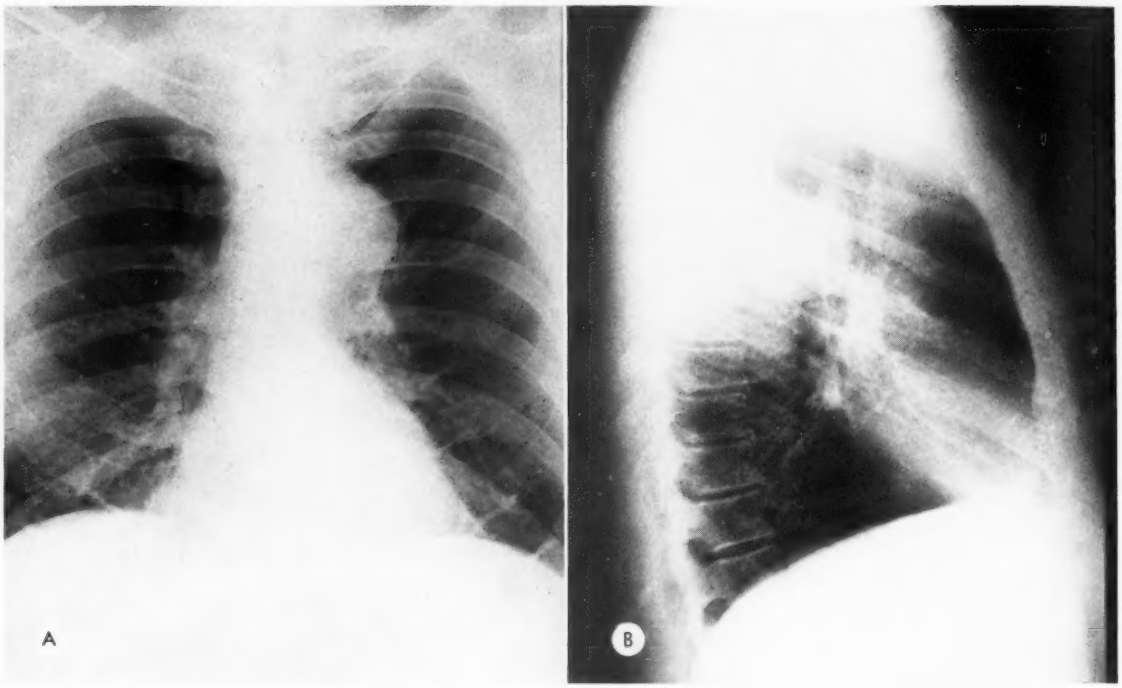

FIG. 5. Case VI (T.B., M-48). (*A* and *B*) Routine posteroanterior and lateral roentgenograms demonstrating discrete mass in the proximal descending aorta with minimal calcification in the wall. Angiocardiograms made elsewhere proved aneurysm.

was admitted to Methodist Hospital in October, 1956, with a history of a crushing injury to the chest in 1941. Three months prior to admission the patient had noted pain beneath the right scapula. On roentgenographic examination an aneurysm arising distal to the left subclavian artery was found (Fig. 4, *A* and *B*). Angioaortogram confirmed this diagnosis (Fig. 4*C*). Serologic tests were negative and there was no evidence of hypertension. On October 23, 1956, using a by-pass pump, the aneurysm was resected and an Ivalon prosthesis was inserted. The patient developed postoperative psychosis and a wound infection which prolonged his recovery but he was eventually discharged on November 17, 1956.

CASE VI. T. B., male, forty-eight years old, was admitted to Methodist Hospital in January, 1957, with the history that in November, 1956, he had been refused insurance because of the presence of a previously undetected thoracic aneurysm. Past history indicated that he had had an automobile accident four years previously in which the chest had struck the steering wheel with resultant rib fractures. Retrospective viewing of the roentgenograms made at the time of the original injury showed enlargement of the aorta (Fig. 5, *A* and *B*). An angiocardiogram made elsewhere confirmed the presence of a traumatic aneurysm. On January 7, 1957, using a by-pass pump, the lesion was resected and a nylon-dacron prosthesis, was inserted. Preoperative studies showed no evidence of lues or hypertension. The resected specimen showed minimal arteriosclerosis in a post-traumatic aneurysm. The patient's postoperative course was uneventful and he was discharged from the hospital eleven days following surgery.

CASE VII. L. F., male, forty-two years old, was admitted to Methodist Hospital for study and treatment in February, 1958. In December, 1957, he had developed pain in the chest with pressure symptoms and a numb feeling. An electrocardiogram had shown no abnormality but chest roentgenograms had demonstrated a mass adjacent to the aorta and evidence of old rib fractures (Fig. 6, *A* and *B*). Previous history revealed that the patient had been in a severe automobile accident in 1939 or 1940 and sustained a severe head injury as well as chest damage. Coma and the apparent minor nature of the chest injury directed attention away from the chest. The patient was discharged from the hospital and no further difficulty was encountered until his induction into the Armed Services in 1942. A routine induction roentgenogram

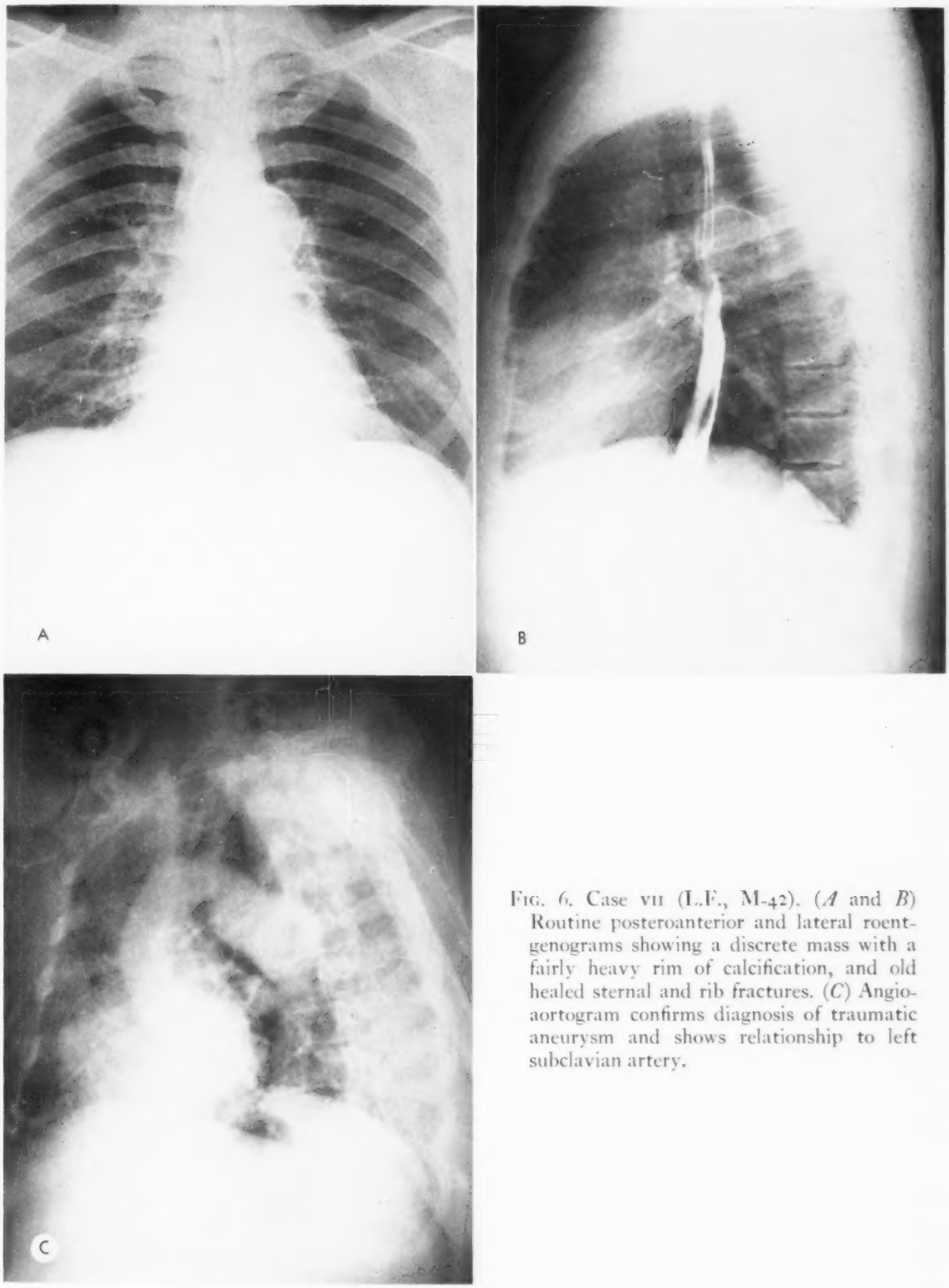

Fig. 6. Case VII (L.F., M-42). (*A* and *B*) Routine posteroanterior and lateral roentgenograms showing a discrete mass with a fairly heavy rim of calcification, and old healed sternal and rib fractures. (*C*) Angioaortogram confirms diagnosis of traumatic aneurysm and shows relationship to left subclavian artery.

showed a mass in the chest, which prompted his release one week after induction, but the patient apparently paid no further attention to the finding until the present illness. On admission to this hospital the findings on routine chest roentgenograms were confirmed. Blood pressure was 150/100 and serologic tests for syphilis were nonreactive. An angioaortogram

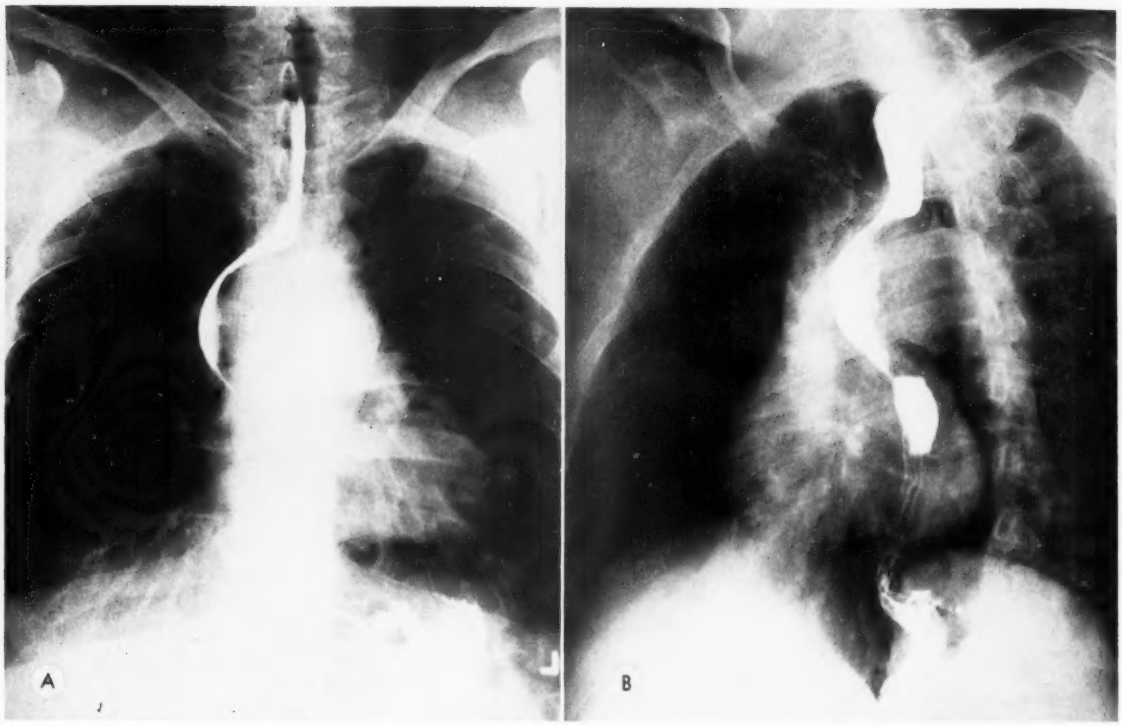

FIG. 7. Case VIII (J.K.B., M-35). (*A* and *B*) Anteroposterior and oblique roentgenograms show a large mass presenting more to the right of the spine than usual but containing a faint rim of calcification which suggests its identity.

(Fig. 6*C*) confirmed the diagnosis of a traumatic aortic aneurysm and on February 18, 1958, this was resected and replaced with a plastic prosthesis using the by-pass pump. The patient did well postoperatively and was discharged ten days later.

CASE VIII. J. K. B., male, thirty-five years old, was admitted to this hospital in May, 1958, with the history of a sense of fullness in the chest with some sharp, substernal, nonradiating pains and a productive cough of approximately one month's duration. Chest roentgenograms made elsewhere showed a mediastinal mass (Fig. 7, *A* and *B*). There was no history of lues and serologic tests for syphilis were nonreactive. Blood pressure was 105/65. Past history revealed that the patient had sustained fractures of the skull and leg in an airplane crash in 1945. No chest roentgenograms had apparently been made at the time and none had been obtained in the interval. On May 8, 1958, a typical traumatic aneurysm was resected using the by-pass pump and the defect was filled with a knit dacron prosthesis. Repeat thoracotomy for evacuation of clots was carried out the same day, but otherwise the postoperative course was uneventful and the patient was discharged eleven days later. Pathologic examination of the resected specimen showed arteriosclerosis and aneurysm formation. There was a localized area of dissection between the media and adventitia.

DISCUSSION

In each of the 8 cases reported there was a history of severe trauma which included injury to the chest with recognized (or unrecognized) injury to the aorta. Abnormality associated with the aorta was subsequently demonstrable and in each instance calcification was present in the abnormal mass. Evidence of old thoracic cage fracture was also demonstrable in all but 1 patient. In none of the patients was there any history of previous venereal disease and there was no serologic evidence on which to base a diagnosis of lues. No significant hypertension was present in any of the individuals and all but 1 were below the age of fifty. Roentgenographically none of the patients showed any evidence of changes in the aorta other

than the localized abnormal process. In each situation the aneurysm was located distal to the origin of the left subclavian artery.

It is anticipated that, in the future, traumatic aneurysm may be discovered in the ascending portion of the aorta or just above the diaphragm. Whether or not the calcification which is present results from localized dissection and the development of a hematoma or whether it is associated with a degenerative process developing after the actual trauma, without major hemorrhage, cannot be determined from the evidence at hand. Subsequent study of the patients in whom more prompt surgical intervention is undertaken may shed further light on the pathogenesis.

CONCLUSION

Traumatic aneurysm of the thoracic aorta should be suspected on routine roentgenographic examination by: (1) its location distal to the left subclavian artery near the junction of the arch and descending portion; (2) calcification in the wall (late cases); (3) evidence of previous trauma to the thoracic cage; (4) age of the patient, without other evidence of vascular disease; and (5) absence of positive serologic findings in a normotensive individual.

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All patients reported in the case histories were on the surgical services of Dr. M. E. DeBakey and Dr. D. A. Cooley.

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SURVIVAL IN AORTIC DISSECTION WITH RUPTURE INTO THE PLEURAL CAVITY*

A CASE REPORT

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IN STANDARD textbooks, and in the literature, dissecting aortic aneurysm is not infrequently reported. In the majority of these cases, death ensues within a few hours after diagnosis. In Shennan's[5] series, 58 per cent died within the first twenty-four hours, and an additional 38 per cent expired in the first week following the acute episode. Mote and Carr[4] reported that about 20 per cent of patients survive the initial episode and a much smaller percentage recover completely.

The surviving patients have been those in whom the dissection re-entered the original channel with the eventual development of a double-barreled aorta. Our patient's dissection, on the other hand, ruptured into the right pleural space and sealed off spontaneously, with subsequent healing. This course of events is, to our knowledge, unique.

Kienböck and Weiss[3] were among the earliest to state that the actual lighter shadow of a dissection could be distinguished on roentgenograms from the aortic shadow in healed cases of "double-barreled" aorta.

Bean and Ponseti[1] have illustrated that dissection of aortic aneurysm has a higher incidence in the following conditions: Marfan's syndrome, coarctation of the aorta, pregnancy, and hypertension. In our patient, a hypertension of several years' duration was present.

Drury[2] has mentioned the characteristic clinical and pathologic picture in healed cases of dissecting aneurysm. The clinical and roentgenographic studies in our patient clearly trace the development of hemothorax resulting from the aortic rupture. The subsequent healing and relatively long term follow-up are also of note.

REPORT OF A CASE

A fifty-seven year old chemical operator was admitted to the Somerset Hospital by ambulance on July 20, 1957, at 12:30 P.M. About half an hour before admission, while walking along the street, he suddenly developed a severe non-radiating pain just medial to the right scapula. He was more comfortable in the recumbent than in the sitting position. There was no faintness or loss of consciousness. He gave a history of high blood pressure of many years' duration, and stated that he was currently being treated with reserpine. Five years previously he had had a right spontaneous pneumothorax.

On examination the temperature was 98.4°F., the pulse rate 88 and the blood pressure 100/70 in the right arm. The patient was apprehensive, in intense pain, and in shock. The skin was cold and drenched with sweat. He was not cyanotic or dyspneic. The pupils were equal and reacted to light and accommodation. The trachea was deviated far to the left. There was equal chest expansion. There was no tenderness of the chest wall. An area of dullness was present in the right interscapular space. No rales or change in breath sounds were noted. The heart was regular in rhythm and shifted to the left. No murmur or gallop was present. The aortic second sound was somewhat accentuated. No abdominal masses or tenderness were elicited. The abdominal aorta could not be palpated. Good strong femoral pulses were palpable bilaterally, but both radial and both carotid pulses were quite weak.

Ten milligrams of morphine sulfate were administered hypodermically and the patient was placed in an oxygen tent. One hour later the patient's condition had improved greatly. His pain had subsided but had not completely disappeared and he was clinically out of shock. The pulse rate was 84, the blood pressure 140/95 in the left arm and 130/90 in the right arm. Both radial and both carotid pulses were now strong.

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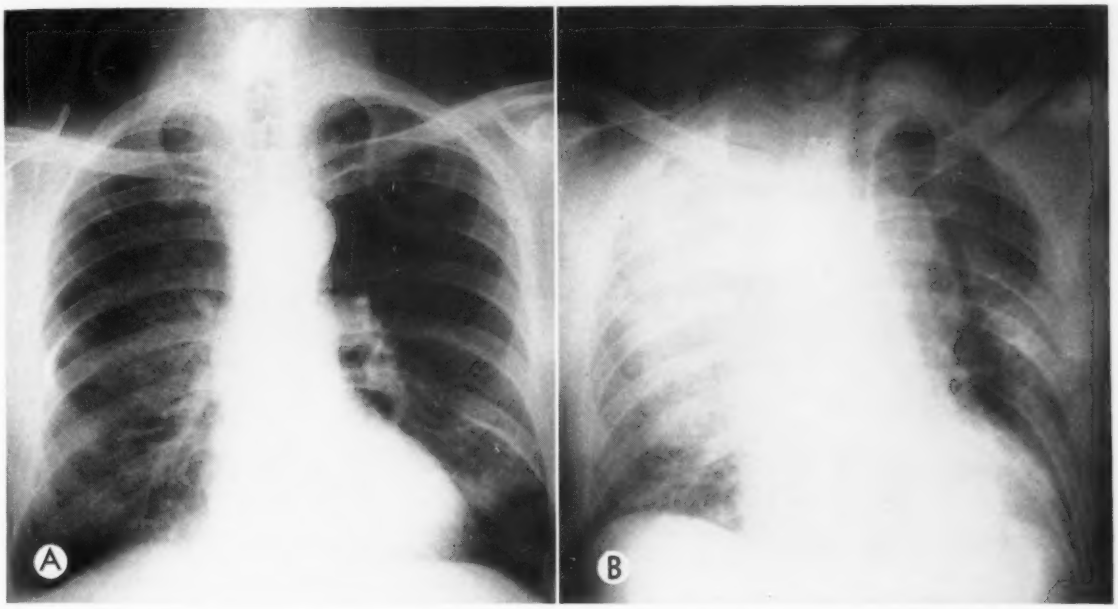

Fig. 1. (*A*) November 22, 1956: The aorta is tortuous and dilated in the thoracic segment. The cardiac shadow is within normal limits and the lungs are free of infiltration. Blunting of the right costophrenic angle represents previous infection. This chest roentgenogram was taken eight months prior to illness. (Reproduced with permission of Dr. Philip J. Cantor.) (*B*) July 20, 1957: Examination two hours after acute episode shows dilated aorta with pronounced widening of the left aortic border. The heart is enlarged and the upper right chest is opacified with hemorrhagic fluid.

A roentgenogram of the chest confirmed the clinical impression of dissecting aneurysm of the arch of the aorta (Fig. 1*B*).

Laboratory work done on the day of admission revealed a hemoglobin of 12.6 gm., red blood cells 4.5 million, white blood cells 17,900, with 75 per cent polymorphonuclears, 20 per cent lymphocytes and 5 per cent monocytes. Urine: specific gravity 1.016, a faint trace of albumin, sugar negative, alkaline reaction, microscopically negative. An electrocardiogram was not remarkable.

By the following day, the patient's condition was much improved. He had no pain except during his infrequent coughing, at which time it radiated down from the right posterior chest to the right flank and iliac region. He was dyspneic when lying on the right side, but more comfortable on the left. The pulse rate was 72, the blood pressure 175/100 on the left and 170/95 on the right. At this time dullness and diminished breath sounds over the entire right posterior chest and at the left base were noted. Roentgenogram of the chest showed cardiac enlargement with massive right pleural effusion (Fig. 2*A*).

On July 24, 1957, the fifth hospital day, the patient's condition had changed. He was noticeably pale and mildly dyspneic. There were signs of fluid in both chests, more on the right side. At this time the hemoglobin was noted to have dropped to 8.2 gm. and the red blood cell count to 3,100,000. A blowing diastolic murmur along the left sternal border was noted. He was given three blood transfusions on successive days and the blood count rose to 11.5 gm. hemoglobin and 4.3 million red blood cells. The murmur of aortic insufficiency disappeared in two days. Roentgenogram of the chest showed increase of the pleural effusion (Fig. 2*B*).

On July 30, 1957, the patient complained of right lower chest and flank pain, and some costovertebral angle tenderness was noticed. The signs of fluid in the right chest remained unchanged (Fig. 3*A*). At this time 1,250 cc. of blood was removed from the right chest by thoracentesis. On August 1, 1957, 400 more cc. of blood was removed (Fig. 3*B*). The patient continued to have pleuritic pain in the right chest of gradually diminishing severity (Fig. 4*A*) until his discharge on August 17, 1957. This required demerol for relief on several occasions. The patient's pulse rate remained between 60 and 80 per minute and the blood pres-

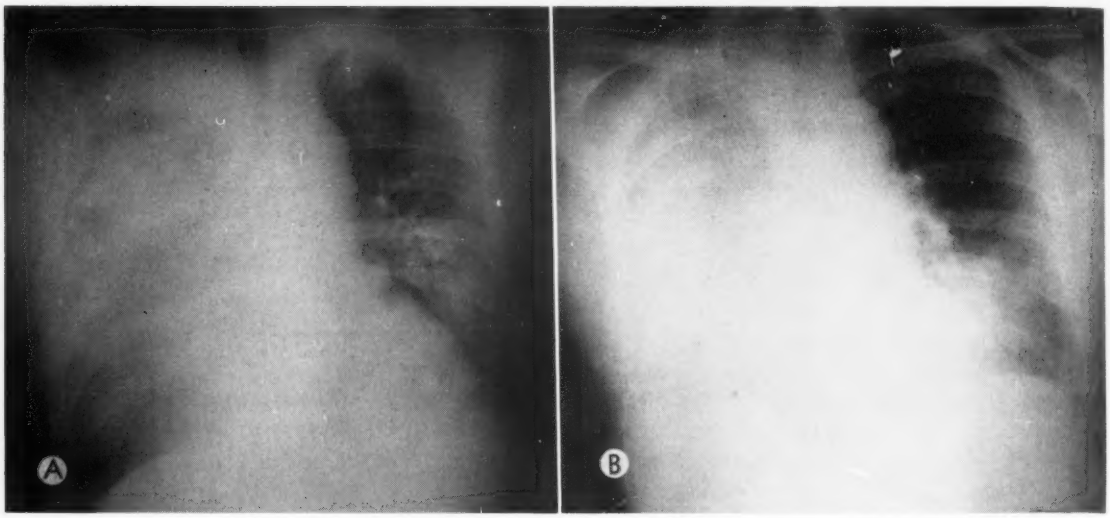

FIG. 2. (*A*) July 21, 1957: One day after Figure 1*B*, roentgenogram of the chest shows further cardiac enlargement with massive pleural effusion on the right. The aortic shadow is still prominent at the arch and the heart and mediastinal structures are displaced to the left. (*B*) July 24, 1957: Three days later, the pleural fluid is increased in extent and the heart is somewhat smaller in size. The fullness in the aortic arch persists.

sure fluctuated between 160/100 and 200/130, averaging about 190/110. Phenobarbital 30 mg. t.i.d., reserpine 25 mg. q.i.d., and apresoline 50 mg. q.i.d. were ineffective in reducing the patient's blood pressure while he remained in the hospital. He was discharged on August 17, 1957, to return to the care of his physician, Doctor Philip Cantor, in Brooklyn, New York. The discharge diagnoses were: (1) dissecting aneurysm of the arch of the aorta with rupture into the right pleural space; (2) right hemothorax; and (3) hypertensive vascular disease. Follow-up chest roentgenograms were taken at three month intervals (Fig. 4*B*).

The patient was re-examined on May 8, 1959. At that time his only complaint was an occasional aching pain in the right lower chest at times of change in the weather. He has con-

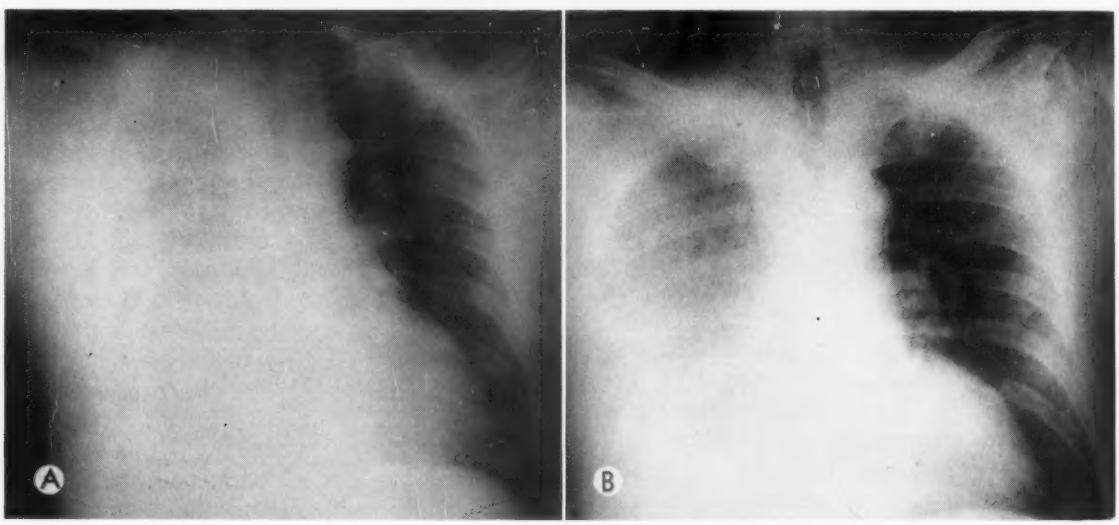

FIG. 3. (*A*) July 30, 1957: Ten days subsequent to dissection and rupture, the right chest is almost completely opacified. The heart size is essentially unchanged, and the aortic arch is wide. (*B*) August 2, 1957: A roentgenogram taken after thoracentesis shows diminution in fluid with heart shadow remaining enlarged. A double wall in the descending portion of the arch is delineated.

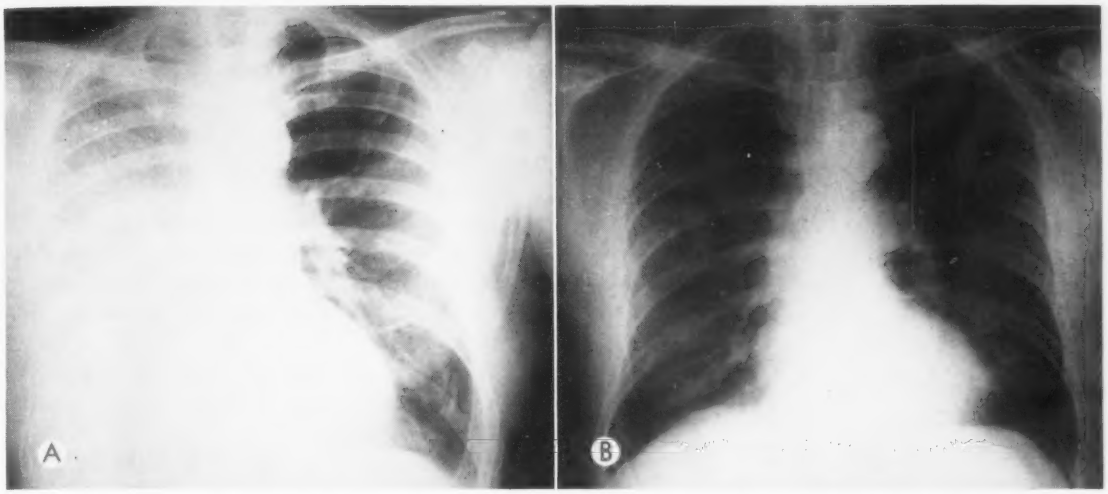

Fig. 4. (*A*) August 16, 1957: Two weeks after Figure 3*B* gradual resolution and absorption of the pleural fluid are demonstrated. The heart is smaller and the aortic arch is narrowed when compared with earlier studies. (*B*) February 11, 1959: A follow-up roentgenogram twenty months after the acute onset shows the cardiac shadow at the upper limit of normal. The aortic shadow is unremarkable, and there has been complete healing in the right chest.

tinued to be extremely nervous, anxious and tense; he has not returned to work. There has been no angina or dyspnea. His wife, a nurse, takes his blood pressure at home. At times of nervous excitement it is as high as 220/120. At other times it is in the neighborhood of 180/90–100. He is taking .75 gm. of diuril daily, 120 mg. of ansolysen daily, 90 mg. of phenobarbital daily, and 2.0 mg. of reserpine daily, all in divided doses.

A complete physical examination revealed a pulse rate of 56 and a blood pressure of 205/120. The general appearance was that of good health. The lungs were clear to percussion. There were scattered fine, moist rales at the right base and also a few at the left base. The heart was not enlarged. The aortic second sound was quite loud. There was no murmur or gallop. The dorsalis pedis pulses were strong. The optic fundi showed some arteriolar spastic narrowing and arteriovenous nicking but were otherwise normal in appearance. The electrocardiogram showed only a mild left ventricular hypertrophy.

SUMMARY

1. A case of rupture of a dissecting aneurysm of the thoracic aorta into the right pleural space has been described.

2. The survival of the patient and subsequent healing up to two years, at the time of submission of this paper for publication, is reported.

3. Clinical and roentgenographic correlation of the disease and follow-up are presented.

4. Survival for this length of time under the foregoing circumstances is unique.

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ANEURYSM OF HEMIAZYGOS VEIN ASSOCIATED WITH PORTAL HYPERTENSION

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IT HAS been known for a number of years that the azygos and hemiazygos veins act as an important means of collateral circulation in cases of portal hypertension. This route is accomplished through the gastric and esophageal veins which then empty into the azygos system of veins.[2] The anatomy of the azygos system of veins has been well described by Abrams[1] in 1957. The importance of this circulation as a bypass between the inferior vena cava and the superior vena cava is especially noted when the numerous variations in the venous system are considered. Aneurysms of the azygos and hemiazygos veins may be caused by an increase in pressure in this system and may be due to congestive heart failure, increased portal venous pressure, anomalous venous drainage from the lungs, absence of inferior vena cava or superior vena cava, persistence of left superior vena cava, anomalous location of azygos or hemiazygos vein, obstruction of superior vena cava or inferior vena cava and Budd-Chiari's syndrome.[1,4] A combination of excessive blood flow and atheromatous change in the veins is thought to be the cause of aneurysm, especially in patients with associated portal hypertension.[2]

REPORT OF A CASE

This is the case of a fifty-four year old white male, who was admitted to Wayne County General Hospital on August 2, 1959 with the chief complaint of shortness of breath at night for a period of one year. He also had an ulcer on his leg. A chronic cough had been present for six to seven years. He has been treated with digitalis for the past year at another hospital with good results. The patient began having signs and symptoms of congestive heart failure when he ceased taking the medication but improved upon resumption of treatment. He was employed as a machine operator but has not worked for a year. His smoking habits were one package of cigarettes a day for many years. He has been a heavy drinker for the past thirty-seven years. Review of systems was essentially normal except for the shortness of breath and leg ulcers.

Physical Examination. This revealed purpura on feet, cataract in the left eye, gynecomastia, varices of the abdominal wall which filled from below upward, ascites, hepatosplenomegaly and pedal edema. The clinical diagnoses were congestive heart failure, emphysema and fibrosis, cirrhosis and purpura.

While in the hospital, his purpura gradually increased and then subsided. Sigmoidoscopic and esophagoscopic examinations were normal.

Laboratory Data. Prothrombin times were below 50 per cent; total protein 6.5 gm. per cent with a 4.4 to 2.1 albumin to globulin ratio; blood urea nitrogen 15.5 mg. per cent; bilirubin 1.4 mg. per cent; fasting blood sugar 94 mg. per cent; thymol turbidity 4.2; thymol flocculation negative; bromsulphalein 37 per cent; alkaline phosphatase 6.2; acid phosphatase 0.1; cephaline flocculation ±; hemoglobin 12 gm.; hematocrit 40 per cent; white blood cell count 5,000; platelet count 125,000; bleeding times were normal and hemogram was normal; cold agglutinins, negative; and creatinine 1.6 mg. per cent. The interpretation of the serum electrophoresis was that of a cirrhotic type of curve. Electrocardiogram was interpreted as showing questionable right ventricular strain.

Roentgen Findings. On admission an upright posteroanterior and lateral roentgenogram of the chest showed a double density behind the heart (Fig. 1 and 2). Roentgenograms of the dorsolumbar spine demonstrated this mass to be to the left of the spine. A barium enema study, upper gastrointestinal series, and aortography were done and no pathologic process related to any of the studies was found. It was noted at the time of fluoroscopy that the mass did not pulsate, was free of the diaphragm and aorta and was separate from the gastrointestinal tract. The mass was more prominent in the recumbent than in the upright position. Laminagrams showed this mass to be paraspinal with no attachment to the spine. The

spine was normal. A diagnosis of a posterior mediastinal tumor was made.

Operative Findings. On September 11, 1959 it was decided to operate on this patient. The findings at surgery were two dilated varices (aneurysms) of the hemiazygos vein just to the left of the spine and above the diaphragm. These varices were not tied or resected because of the possibility of being important collaterals due to his cirrhosis and portal hypertension.

DISCUSSION

Aneurysms of the hemiazygos vein should be included in the differential diagnosis of posterior mediastinal masses, especially when the mass changes in shape and size with change in position and intrathoracic pressure.[5] Lying down will increase the size, while standing up will decrease it. The size will also decrease with the Valsalva maneuver and increase with the Müller maneuver. The fact that the above signs are present along with a nonpulsating mass, which is not attached to the gastrointestinal tract, diaphragm or aorta, should make one consider a venous aneurysm even more. Usually, there is some underlying cause for the aneurysm, such as increased pressure in the inferior vena cava, superior vena cava or portal vein.

FIG. 1. Posteroanterior roentgenogram of chest demonstrating double mass density superimposed over lower dorsal spine and cardiac silhouette.

FIG. 2. The mass densities shown in the left lateral roentgenogram are retrocardiac and lie in the posterior mediastinum.

The diagnosis can be substantiated by azygography,[3] through intraosseous injection of the posterior ribs or spinous process. The venous drainage from the spine and ribs (via intercostal veins) is to the lumbar vein which becomes the azygos and hemiazygos vein at the level of L 1 and L 2.

The diagnosis of aneurysm of the hemiazygos vein is important in order to prevent unnecessary radiation therapy or thoracotomy to the patient.

SUMMARY

1. A case of two aneurysms of the hemiazygos vein is presented.

2. Roentgen findings typical of this condition are given as an aid to arriving at a proper diagnosis.

3. Various diagnostic means are mentioned including azygography.

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EVALUATION OF VERTEBRAL VENOGRAPHY*

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CLINICAL interest in the vertebral veins, the systemic vein bypass system, was stimulated only recently. The credit for this goes to Batson,[2] who first postulated the metastatic spread via this venous reservoir to explain "paradoxical" metastasis. Several roentgenographic studies of the vertebral venous system have been made and the value of the clinical application has been discussed.[4,5,6]

The present study was initiated to evaluate the use of vertebral venography in the early detection of vertebral metastases. At the same time, its application to the diagnosis of spinal canal tumors and to herniated nuclei pulposi was to be attempted. Esophageal varices have presented a problem in roentgenographic demonstration and it has been suggested that visualization of the azygos and hemiazygos veins might offer some help in this direction; it was hoped that the diagnosis of esophageal varices by vertebral venography could also be evaluated.

In this study vertebral venography was attempted in 31 patients. The successful investigation included 11 cases of malignancy without known metastasis, 4 cases of obvious vertebral metastases, 4 cases of esophageal varices, 2 cases of spinal cord tumors (meningiomas), 2 cases of postoperative spinal defects, 1 case of herniated nucleus pulposus at L5-S1, and 1 case of congenital heart disease. In 6 patients the examination was unsuccessful.

METHOD

The tip of a gauge No. 14 thin-walled needle with a stylet was inserted into the femoral vein percutaneously immediately below the inguinal ligament; a plastic tube, gauge No. 13, was connected to the needle and, using a Robb-Steinberg syringe, 40 cc. of 70 per cent urokon was injected manually after abdominal compression had been applied over the inferior vena cava at about the level of L4. A cuff about each thigh was inflated to about 110 mm. Hg pressure to insure cephalad flow of all the opaque medium.

Before any pressure was applied to the abdominal wall, the abdomen was examined to exclude aortic aneurysm or other masses which might present serious complications if compressed. Measurement of the pressure needed to obstruct the inferior vena cava proved difficult to obtain; it was considered inaccurate and of little value. A considerable amount of pressure was applied at first by an abdominal compression band fixed to the table. Later, an aortic clamp (Hasselhorst clamp) was found to be more useful for the purpose of applying abdominal compression. Pressure was removed as soon as the exposures were made. The time required for the injection varied from approximately two to four seconds. The exposure was made immediately after completion of this injection; a single 14×17 inch film was used. When multiple roentgenograms were taken with the Sanchez-Perez cassette changer, the first exposure was started about one-half second before completion of the injection. Whenever possible, lateral as well as anteroposterior views were obtained and the region of the azygos and hemiazygos veins was included in the field examined. An arbitrary limit of 80 cc. of opaque medium in two injections was set.

Puncturing the femoral vein was quite easy after it was realized that the direction of the needle should be almost perpendicular with its point angled very slightly cephalad and mediad. The needle was stabilized by clamping it adjacent to the skin with a mosquito forceps so that the forceps acted as a brace. When the patient

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complained of backache at the moment of the injection, it was considered a good indication that the compression of the inferior vena cava was effective and that the contrast medium was bypassing through the paravertebral veins. Pain was not always present but occurred in most of the successful examinations.

All the patients were prepared with 50 to 100 mg. of demerol intramuscularly and were examined in a fasting state.

RESULTS

Visualization of any of the vertebral venous system was considered the criterion for a successful examination. The examination failed completely in 4 cases: due to inadequate abdominal compression in 2, extravasation in 1, and both in another. There were 2 partial failures in which the vertebral veins were visualized only in a limited, localized area. In 5 cases there was only unilateral filling of the ascending lumbar veins.

The epidural veins were visualized in 21 cases and the opaque medium was demonstrated as far cephalad as T9 or T10 in 16 cases. Only 6 showed filling cephalad to this level with 3 reaching T7, 1 reaching T5 and another one reaching T3. Partial filling of the intravertebral and intervertebral veins occurred in a majority of cases, while the intercostal and lumbar veins filled at their proximal ends in only a few cases.

In all 4 cases with far advanced, widespread spinal metastases, there was no evidence of obstruction, compression, displacement, or abnormality of any other kind involving the vertebral veins (Fig. 1). Three of these patients had metastasis from the breast while one had metastasis from the prostate.

In one case of meningioma at T10 demonstrated by myelography, there was a question as to whether or not the epidural veins were blocked. However, since in the majority of cases the opaque medium does not pass beyond T9 or T10, it is more likely that in this case the opaque medium had disappeared from the epidural veins at the tumor level because of shunting into the azygos and hemiazygos veins.

In a case of subarachnoid block at T_3 due to spinal tuberculosis, the epidural veins filled only to T9. In another patient who had had a meningioma at T7 to T9, the epidural veins were visible only up to T12. In another case following surgery for a herniated nucleus pulposus at L_4, no venous distortion at the site of surgery could be shown. The visualized internal vertebral plexus at L_5-S_1 in another case gave no roentgenographic evidence of the herniated nucleus pulposus which was present.

The width of the azygos vein (Fig. 2), measured directly on the roentgenogram made at a 40 inch distance, was determined at the level of T8 (Table I) in 15 cases and varied from 5 to 9 mm. in 12 cases. It was 11 mm. in a case of meningioma of the spine, 12 mm. in a case of esophageal varices, and 17 mm. in a case of a congenitally small or absent thoracic portion of the inferior vena cava. In the 3 measurable cases of esophageal varices, the azygos vein at the level of T8 was 7 mm., 8 mm., and 12 mm.

The transverse portion of the azygos vein, measurable in 9 cases, was 9 to 14 mm. except in 1 where it was 20 mm. (Table II). It was 13 mm. in a case of esophageal varices, 14 mm. in a case of spinal cord meningioma and 20 mm. in the case of congenital cardiovascular disease.

The measurement of the azygos vein at its junction with the superior vena cava has been given as 8 to 12 mm. by Lessmann and his co-workers.[5] These authors do not state the number of cases used to obtain these measurements, but from their discussion it is presumed that the measurements were obtained from only 5 cases which were considered to be normal.

In 3 of the 4 cases of esophageal varices, the azygos vein was measurable. One of these showed questionable dilatation at the level of T8 (12 mm. and at the horizontal portion (13 mm.). There was no dilatation of the azygos or hemiazygos veins or retrograde filling of the esophageal

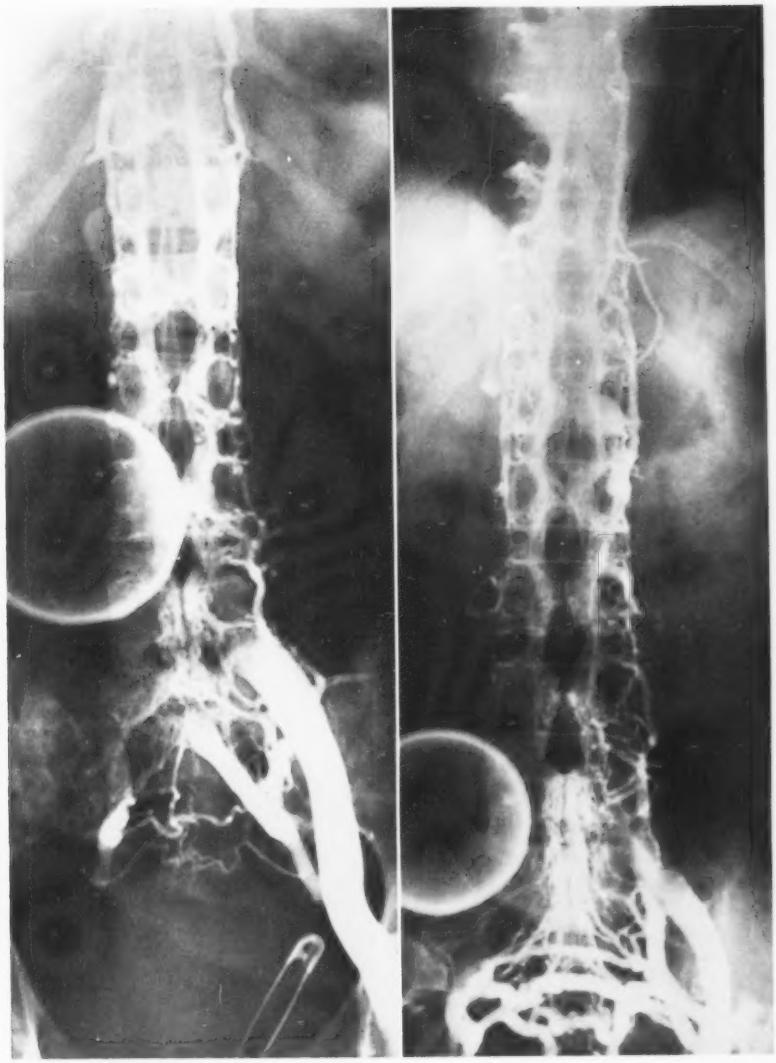

Fig. 1. (*Left*) Roentgenogram of a patient with diffuse, advanced osteolytic and osteoblastic spinal metastases, which were obvious on the plain roentgenograms although not well shown on this reproduction. (*Right*) Roentgenogram of a normal patient. No appreciable difference is evident in the vertebral venous plexus of these two patients. The large opaque rings represent part of the abdominal compression device.

veins in the remaining 2 cases. The number of cases of esophageal varices for this study was limited.

A rounded mass in the right upper mediastinum seen on a conventional chest roentgenogram (Fig. 3) in one patient (J.S.) proved on vertebral venography and surgery to be a huge azygos vein due to a congenitally small or absent thoracic portion of the inferior vena cava (Fig. 4 and 5). This patient had a correction of an interatrial septal defect by open-heart surgery at which time the inferior vena cava in the thorax could not be definitely located.

Table I

WIDTH OF AZYGOS VEIN AT T8 LEVEL

Size in mm.	5	6	7	8	9	10	11	12	17
No. of Cases	3	3	1	2	3	0	1	1	1

Note: At the level of T8 in all cases, the width of the azygos vein measured 9 mm. or less except in a case of meningioma of the spine (11 mm.), a case of esophageal varices (12 mm.) and a case of congenital absence of the proximal inferior vena cava (17 mm.).

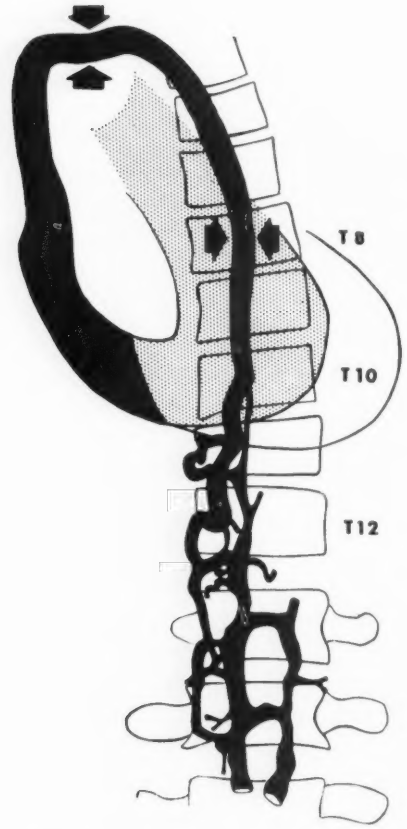

FIG. 2. Drawing of the azygos vein showing the points where measurements were taken, one at the level of T8 (lower arrows) and the second in the horizontal portion of the azygos vein just proximal to its junction with the superior vena cava (upper arrows).

Vertebral venography revealed displacement of the azygos vein along with the mediastinal structures secondary to atelectasis in 2 cases, but gave no significant information more than that obtained from the conventional chest roentgenograms. Compression of the origin of the inferior vena cava by a mass (etiology not proved) in one case resulted in good visualization of the vertebral venous system without the use of abdominal compression, but this added no significant information since the mass was noted both on physical examination and on conventional roentgenograms of the abdomen.

In all lateral views of the vertebral venograms, the ascending lumbar veins obscured the epidural veins and longitudinal sinuses (Fig. 6). The anterior external venous plexus usually does not fill well.

Aortography, attempted by femoral injection in one case, resulted in good visualization of the aorta and its renal branches (Fig. 7).

TABLE II

WIDTH OF AZYGOS VEIN AT TRANSVERSE PORTION

Size in mm.	9	10	11	12	13	14	20
No. of Cases	1	0	2	3	1	1	1

Note: The diameter of the horizontal segment of the azygos vein measured 12 mm. or less in 6 of 9 measurable cases. In a case of esophageal varices it was 13 mm. In a case of meningioma of the spine it was 14 mm. and in a case of congenital absence of the thoracic part of the inferior vena cava it was 20 mm.

DISCUSSION

In 4 cases of far advanced vertebral metastasis, the vertebral venous system ap-

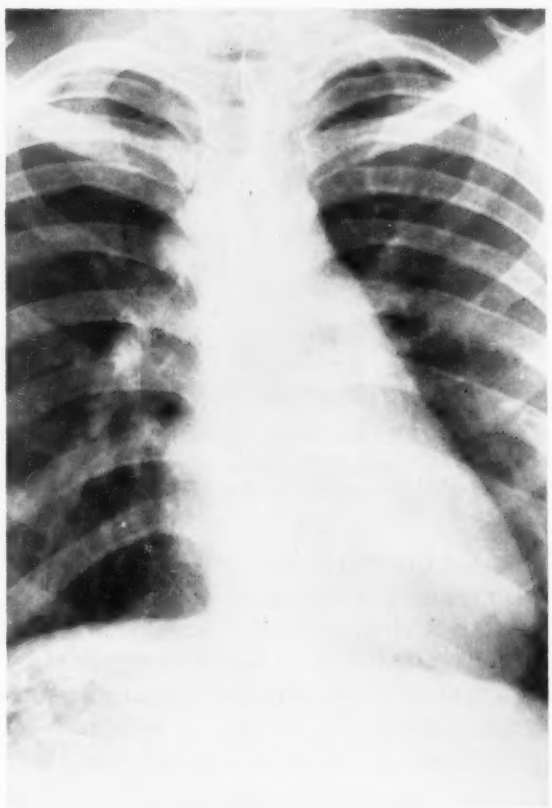

FIG. 3. (J.S.) On the conventional roentgenogram, a rounded mass in the mediastinum can be seen lying just above the right main bronchus. The impression on the esophagus near the upper margin of the aortic arch probably represents the right subclavian artery arising from the left and crossing behind the esophagus.

peared to be unaffected in any way. This was discouraging since the main purpose for undertaking this study was to find a method of demonstrating vertebral metastases at an early stage before they reveal their presence by conventional roentgenography. Helander and Lindbom[4] demonstrated compression of the vertebral venous plexus by vertebral venography in a case of metastatic Hodgkin's disease of the spine, but the destructive lesions were already visible on plain roentgenograms.

The wide variation in the size of the azygos vein makes it unlikely that anything less than marked dilatation of this vessel can be demonstrated. Thus, the employment of vertebral venography to visualize esophageal varices at an earlier stage than is possible by conventional roentgenographic methods appears to be of questionable value. Thorough evaluation, however, requires comparison of the effectiveness of the various methods of examination for esophageal varices in a larger number of cases than were available for the present study.

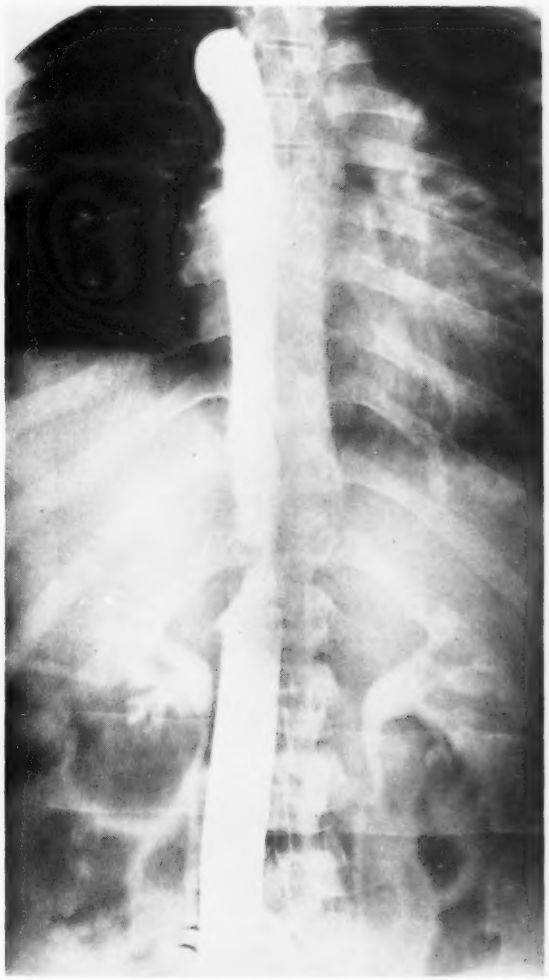

Fig. 4. Same case as in Figure 3. Inferior vena cavogram without abdominal compression showing the inferior vena cava emptying into the azygos vein.

Fig. 5. Same case as in Figure 3 and 4 showing the filling of the vertebral venous plexus and the azygos vein when abdominal compression was applied. The right mediastinal mass was proved to be an enlarged azygos vein by this examination and at surgery. Patient's interatrial septal defect was corrected.

In the lateral view, the ascending lumbar and epidural veins are projected over each other (Fig. 6). As a result, small displacements of the epidural veins cannot be shown and only large lesions causing gross displacements are demonstrable. Obstruction of the venous plexus behind the herniated disk visualized in the anteroposterior projection has been demonstrated elsewhere[4] in 3 cases of herniated nucleus pul-

FIG. 6. A lateral view venogram showing the projection of the ascending lumbar veins over the epidural veins and longitudinal sinuses (retouched).

posus. The variable filling of this plexus, however, would make the significance of nonfilling questionable. Myelography is more certain and a more easily applicable technique for the demonstration of this pathology. Diagnosis of spinal cord tumors might also be made using vertebral venography but no advantage can be seen over the use of conventional myelography. In addition, most spinal cord tumors occur in the mid-thoracic spine, a point to which radiopaque filling of the epidural veins usually does not extend.

On about two-thirds of routine chest roentgenograms, the azygos vein may be visualized and Fleischner and Udis[3] indicate that the maximum width of the normal azygos shadow on routine chest roentgenograms, including the wall of the trachea, is 5 to 6 mm. Enlargement occurs where there is interference with flow of blood (a) into the right auricle due to right heart failure, cardiac tumor, pericardial diseases, and mediastinal mass; (b) in the inferior vena cava by ligation, thrombus or mass; (*c*) in the portal system due to cirrhosis, tumor, thrombosis, and trauma; (*d*) by congenital venous abnormalities, including both anomalous pulmonary venous returns and anomalous abdominal venous system. In idiopathic dilatation the azygos vein

FIG. 7. Aortogram obtained after intravenous injection of 40 cc. of 70 per cent urokon into the femoral vein.

is enlarged but without associated disease. There are times when it is impossible by conventional roentgenography or by laminagraphy to determine whether a rounded soft tissue mass, lying in the right mediastinum immediately above the right main bronchus, is granuloma, tumor or an enlarged azygos vein. It is here that venography was found to have its most useful and important application as demonstrated in patient J.S., who had an anomalous venous return. The proximal inferior vena cava was either very tiny or absent, and the blood usually carried by this vessel passed through the azygos vein instead and caused it to be enlarged (Fig. 3, 4 and 5).

It may be possible at times to demonstrate the presence of suspected mediastinal masses, shown poorly or not at all on conventional chest roentgenograms, by visualization of the azygos and superior vena cava, but this situation has not arisen here. Similarly, in regard to masses in the true pelvis, these may be demonstrated by injection of opaque medium into the femoral vein during compression of the inferior vena cava.

Aside from utilization of femoral vein injection for vertebral venography and for inferior vena cavography, this method of intravenous injection, which is quite easy to perform, was found to provide a very useful route for intravenous cardiac and aortic angiography. The advantages over the more conventional approach via the veins of the antecubital fossa are: (a) lower pressure, (b) larger veins, and (c) the lesser distance from the heart. These factors all result in less resistance and allow more rapid injection, with the radiopaque material tending to travel as a bolus so that a higher degree of opacification is obtained (Fig. 7).

CONCLUSIONS

1. Vertebral venography has a very useful application in the differential diagnosis of mediastinal masses from enlarged azygos veins.

2. There are a few other practical applications for this roentgenographic technique. On occasion, its use may be indicated in cases of lesions affecting the spinal cord below the level of T10 when myelography cannot be performed for some reason or when epidural varices are suspected. Its application in the diagnosis of mediastinal or pelvis masses or venous compression might be indicated at times.

3. The results of employing vertebral venography in the search for vertebral metastases have proved to be very disappointing, and the method is considered valueless for this purpose.

4. In cases of esophageal varices, diagnosis by vertebral venography depends on the indirect sign of azygos (and hemiazygos) vein enlargement. Since considerable variation in the size of the azygos vein exists normally, this method exhibits a large degree of unreliability in mild cases.

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INTRAVENOUS AORTOGRAPHY*

TECHNIQUE AND CLINICAL ASPECTS

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TECHNICAL advances in vascular surgery made during the past decade have created a need for safe and accurate diagnostic procedures in the roentgenologic demonstration of the thoraco-abdominal aorta and its major branches. Many lesions previously considered to be only of pathologic interest are now amenable to direct operative approach and repair. Translumbar aortography, originally introduced by dos Santos *et al.*,[6] is still the most widely used method for visualizing the abdominal aorta. However, this procedure has been associated with a considerable number of serious complications and some deaths.[1,4,5,10,11] McAfee and Willson[13] found a complication rate of 1.02 per cent in reviewing 12,832 translumbar aortographies. The mortality rate was 0.28 per cent. Because of the complication risk, there has been considerable reluctance on the part of many surgeons to perform aortographies and several authors have abandoned the procedure completely.[10,12]

With the exception of the rare case of allergic reaction to the contrast material, complications associated with aortography involve the local site of blind aortic puncture or arterial catheterization. These complications consist of either direct trauma to the vessel and surrounding structures or damage secondary to massive injection directly into the arteries. In an effort to obviate these dangers a venous method of aortography has been developed.[2,3,9]

Basically, intravenous aortography depends on obtaining properly timed roentgenographic exposures of the aorta following the rapid intravenous injection of a large amount of concentrated opaque material. The arrival of the contrast material in the aorta is predetermined by a vein to aorta circulation time, which establishes the interval between venous injection and aortic opacification.

The introduction of angiocardiography by Robb and Steinberg[14] showed clearly that visualization of the thoracic aorta could be accomplished from the venous side. Evans *et al.*,[7,8] Van Velzer and Lanier[17] and others[19] have developed this technique further for the visualization of renal masses. In several of their published works, excellent delineation of the abdominal aorta is present. However, to our knowledge, the venous route has not been previously utilized for the routine delineation of the abdominal aorta and distal branches in suspected vascular disease.

TECHNIQUE

Under local anesthesia a No. 280 polyethylene catheter is inserted into the median antecubital vein and advanced 3 or 4 inches up the arm (No. 13 needle fits snugly into this catheter). Fifty microcuries of I^{131} labelled renografin,‡ 2 cc. of stable renografin 76 per cent (an intravenous test dose), and between 60 and 75 cc. of saline are then injected rapidly into the polyethylene catheter. A collimated scintillation counter is held over the abdominal aorta or over that vessel which is to be examined roentgenographically. Impulses are fed from the scintillation counter through a rate meter to an Esterline Angus recorder, and an accurate arm vein to abdominal aorta circulation time is thus ob-

‡ Kindly supplied to us by E. R. Squibb & Sons, New York, New York.

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tained (Fig. 1 and 2, *A* and *B*). In order for the circulation time to be most accurate, it is necessary to use a volume of material approximating that of the main injection, and this is the reason for utilizing 75 cc. of saline along with the I^{131} labelled renografin. If a small volume (2 to 5 cc.) is used, the circulation time may be up to five seconds slower than with the large amount.

Where a rate meter is not available or where a permanent record of circulation time is not desired, one can obtain as accurate a circulation time by simply holding a collimated counter over the aorta and timing the appearance of rapid "clicking" on a scaler.

The contrast material, consisting of between 65 and 100 cc. of 85 or 90 per cent diatrizoate (hypaque* or renografin), is then injected into the catheter as rapidly as possible. Following a pause equal to the arm vein to aorta circulation time as previously determined, roentgenograms of the abdomen are exposed in either one or two planes. Both the preliminary and the main injections are made with the aid of a steel syringe in a simple lever hand injector. Utilizing this injector, the entire volume of contrast material can be delivered in between two to four seconds, a feat we have been unable to accomplish using a standard syringe. It is necessary to warm the concentrated diatrizoate prior to injection.

FIG. 1. Photograph illustrating injector and apparatus for detecting and recording isotope circulation time. The radioactive tracer material and, in a second injection, the radiopaque material is introduced with the aid of a steel syringe in an Elema-Schönander hand injector. The radioactivity is monitored over the abdominal aorta using a probe scintillation counter connected to a transistorized rate meter and Esterline Angus recorder.

For the majority of our studies, we have utilized the Schönander biplane apparatus, taking roentgenograms at 1 per second for approximately eight seconds. On several studies a single roentgenogram of the abdomen has been exposed using the Bucky

* Kindly supplied by Winthrop Laboratories, New York, New York.

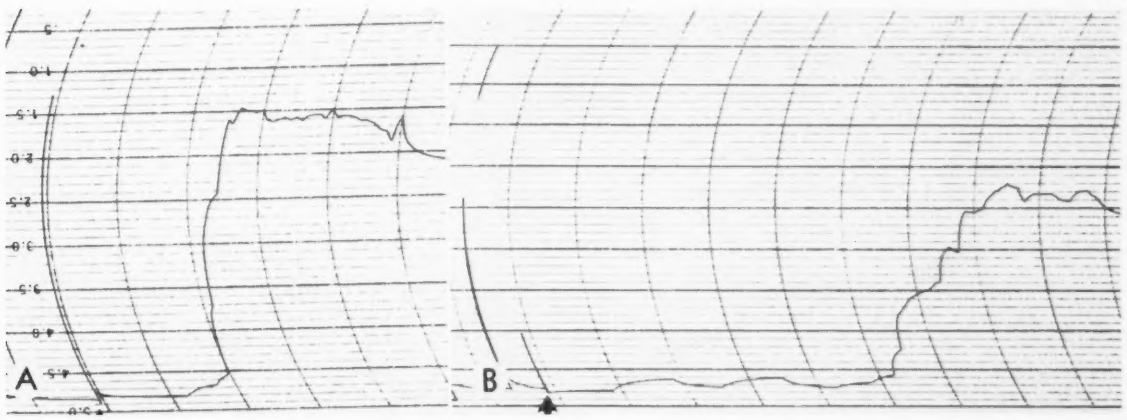

FIG. 2. Tracings of isotope circulation times from antecubital vein of the right arm to abdominal aorta. (*A*) Normal pattern of circulation showing sharp rise in activity at eight seconds following injection. (*B*) Slow circulation in an eighty-four year old male with probable dilution of the isotope. Note the gradual rise in activity twenty-six seconds after injection.

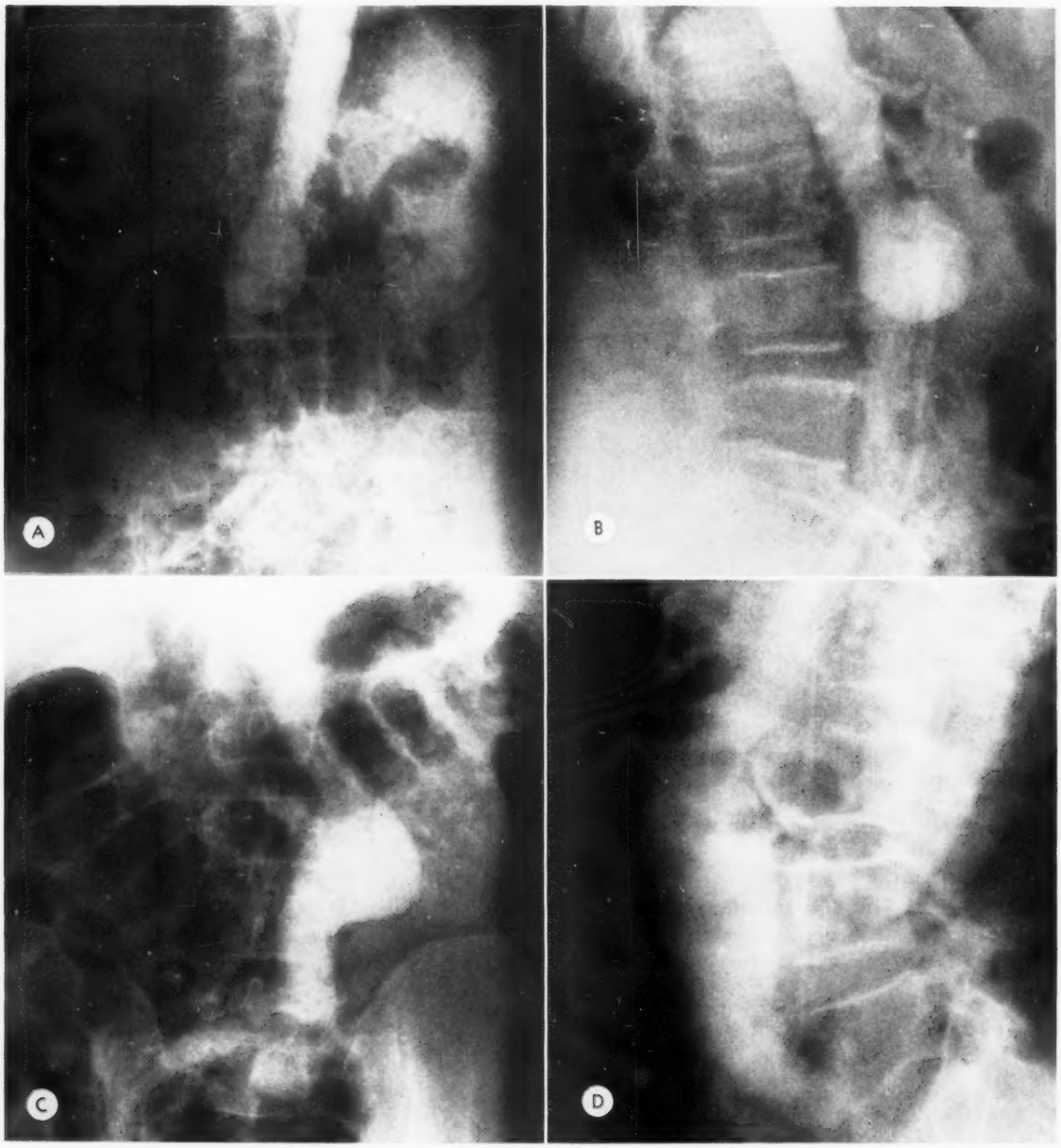

FIG. 3. Abdominal aortic aneurysms. (*A*) Saccular aneurysm proximal to normal bifurcation of the aorta. (Fogging on the right side of the film is due to scattered radiation from lateral exposure taken simultaneously.) (*B*) Lateral view of case shown in *A*. The superior mesenteric artery is plainly visible in this projection. Two projections of an aneurysm are frequently of value to the surgeon. (*C*) Large abdominal aortic aneurysm with a clot causing a shelf-like appearance on the left side. Distal to the shelf defect, the aorta is also dilated and was found to be involved in the aneurysm at surgery. (*D*) Lateral view of case shown in *C* indicates that the aneurysm extends further inferiorly than is apparent on the anteroposterior view.

diaphragm. We have found that an excellent delineation of the aorta and iliac vessels can be obtained using this latter technique with a low milliamperage—long time exposure (up to eight seconds). This allows sufficient time for the contrast material to fill all of the major vessels. In those cases where delineation of the femoral vessels is desirable, a portable machine is centered over the thighs and a single long exposure

is made at low milliamperage. An adequate demonstration of the femoral arteries is obtained by this method.

Timing of the roentgenograms is of primary importance, particularly if one is using a single exposure of short duration. If a rapid changing apparatus is being used, exact timing is not as important and it is only necessary to commence the exposures before the material has passed through the aorta. In 35 cases, we have combined decholin with our isotope-labelled renografin in the preliminary injection. Those patients with fairly normal circulation times and fairly normal abdominal vessels showed no significant difference between the decholin circulation time to the tongue and the isotope circulation time to the abdominal aorta. However, patients who have abdominal aneurysms or considerable atherosclerotic disease in the abdominal aorta may show a difference in circulation time anywhere from one to five seconds with the time to the abdomen being longer.

Fig. 4. Large aneurysm arising below the origin of the renal arteries and extending down to involve the bifurcation and the proximal common iliac arteries.

Fig. 5. Well opacified aorta showing aneurysm arising below the left renal artery. There is an abnormally low right renal artery which comes directly off the aneurysm. The iliac vessels are patent although tortuous. Hepatic and splenic arteries are well visualized.

We have found the venous cut-down and insertion of the polyethylene catheter to be necessary in order to prevent blowing the vein off the end of a needle when a large volume of contrast is injected under considerable pressure. Extravasation into the soft tissues is avoided.

RESULTS

Forty-six thoracic and 158 abdominal aortographies have been performed with the intravenous technique. Adequate concentration of opaque material for diagnostic visualization of the aorta has been obtained in all of the thoracic and 91 (91 per cent) of the abdominal cases. In 5 cases the failure of visualization was due to mechanical malfunction of the rapid changing apparatus. In 4 cases the technique was adequate, but insufficient concentration of opaque material was present in the ab-

FIG. 6. Diffuse tortuosity six years after aneurysmorrhaphy and fascia lata wrap with aneurysmal dilatation over the third lumbar body. There are bilateral iliac artery aneurysms which were not appreciated clinically. The superior mesenteric artery is unusually large.

dominal aorta for diagnostic visualization.

The age of the patients has ranged between twelve and eighty-six years, with the majority being in their seventh and eighth decades. Average circulation time in the adult is ten to twelve seconds, but the time has varied between seven seconds (twelve year old child) and twenty-seven seconds (eighty-six year old man).

Among the abdominal cases 25 aneurysms have been demonstrated. Three patients had aortic occlusion and 15 iliac artery occlusions were found. In 15 instances diffuse aortic atherosclerosis was present without aneurysm and 17 studies were done following grafting procedures. There was a large group (54 cases) in which the intravenous aortogram was normal or showed only minor abnormalities. These were mostly patients with suspected aneurysms or possible kidney disease. Two renal tumors, the congenital absence of a kidney, and renal atrophy have also been diagnosed.

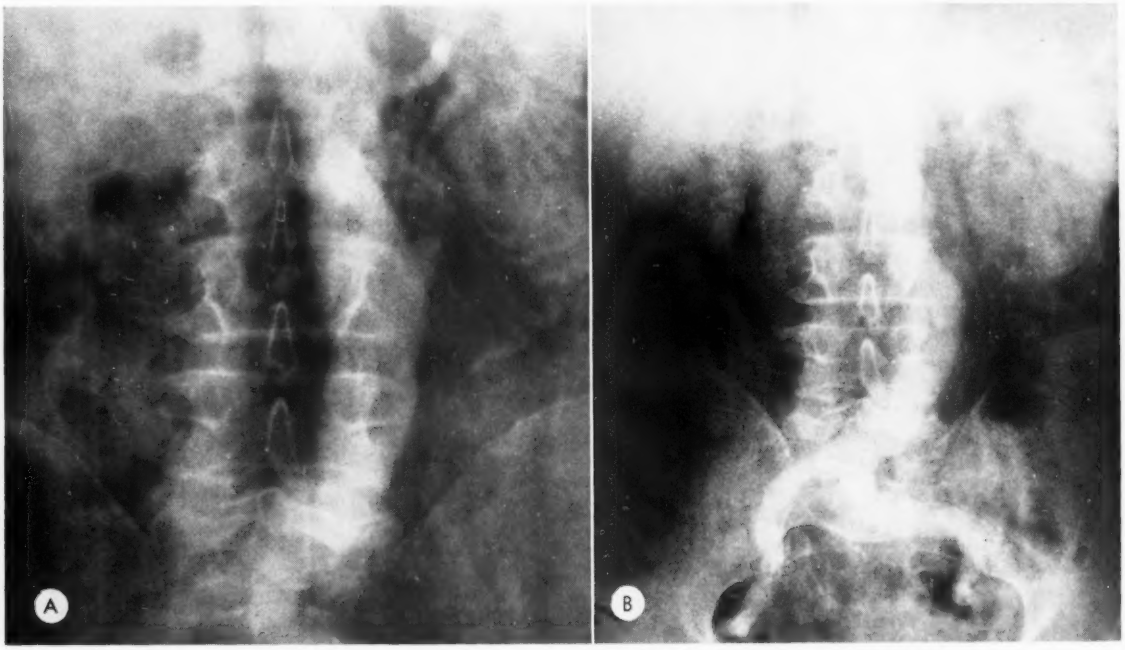

FIG. 7. (*A*) Aneurysm formation in an aortic homograft twenty-six months after its implantation. The nipple-like projection on the left side is clearly visualized. At surgery the wall surrounding this projection was extremely thin. (*B*) Same patient eight days after the aneurysm and graft were oversewn and wrapped with teflon. The aorta is slightly more tortuous, but the projection to the left is no longer present.

Fig. 8. Aortic thrombosis in a twenty-nine year old diabetic Negro female. A previous sympathectomy had been done for peripheral vascular disease. No demonstrable run-off is seen. Patient eventually required bilateral amputation.

Fig. 9. Bilateral iliac artery occlusion. The occlusion is complete, but segmental on the left side. It is incomplete on the right side. There is good run-off bilaterally.

COMPLICATIONS

There have been no serious complications or deaths from this procedure. The patients routinely experience considerable flushing and a fairly marked wave of heat. This lasts for two to three minutes. Two individuals experienced transient nausea without vomiting. An additional 2 patients experienced a headache following the procedure which lasted between five and ten minutes and disappeared spontaneously. In 3 cases phlebitis occurred in the arm in the region of the catheter. In all 3 the catheter had been left in overnight. Following this experience the catheters have been removed after completion of the procedure, and there have been no subsequent cases of phlebitis.

CLINICAL ASPECTS

Intravenous aortograms have been most useful in the pre- and postoperative evaluation of patients with suspected or known abdominal aortic aneurysm (Fig. 3, *A*, *B*, *C* and *D*). Although many authors feel that aortography is unnecessary in making the diagnosis of aortic aneurysm and that physical findings suffice, tortuosity of the aorta without aneurysm or a normal aorta in a thin patient have been suspected of representing aneurysm and unnecessary surgery has been performed. In weighing the advantages and disadvantages of routine aortography, one must take into account the morbidity and mortality from the procedure. Since morbidity has been fairly significant with blind puncture abdominal aortographies, there probably is considerable justification for not routinely using direct aortography for demonstration of aneurysms.

The intravenous method, however, is simple, safe and rapid to perform. It yields valuable information as to the extent of the aneurysm and the condition of the bifurcation of the aorta (Fig. 4). It will also reveal the presence or absence of renal artery involvement (Fig. 5), and may indicate

FIG. 10. Right femoral artery occlusion. A 14×17 inch cassette was placed under the thighs and exposed for six seconds. A few collateral vessels are seen on the right side, but there is no evidence of superficial femoral filling.

the presence of multiple aneurysms where only one was clinically suspected (Fig. 6).

Additional intravenous aortograms may be of value in the postoperative period following aortic grafting procedures. This is particularly true in the group where homografts have been implanted. In a number of reported cases, homografts have been shown to develop tortuosity, dilatation, and re-formation of aneurysm. A case of localized dilatation in such a graft twenty-six months after its insertion was recently discovered following routine intravenous aortographic study (Fig. 7, *A* and *B*).

Occlusion of the aorta, the iliac, and the femoral arteries is also well visualized on intravenous aortograms (Fig. 8). The intimate details of the run-off circulation are frequently not well seen. However, the local area of the block is well visualized. We have found this procedure to be of particular value in cases of iliac artery thrombosis at or near the bifurcation of the aorta (Fig. 9). An extra 14×17 inch cassette placed under the thighs and exposed, using a portable roentgen-ray machine, will give information as to the patency of the femoral arteries (Fig. 10).

Visualization of the thoracic aorta by angiocardiography was emphasized by Steinberg *et al.*[15,16] as early as 1940. The large amount of contrast material utilized in these studies gives dense visualization of the thoracic aorta and its major branches. Roentgenograms are made in two planes starting three to four seconds after the injection and in 46 consecutive studies good visualization of the thoracic aorta had been obtained.

As Evans and his co-workers[7,8] have clearly demonstrated, the study of the kidneys in both the arterial phase and the nephrographic phase following intravenous injection of an opaque medium will frequently yield fruitful results in differentiating tumors from cysts, and also in studying other vascular abnormalities of the kidneys. We believe that intravenous aortography also has a place in the study of hypertension unexplained by other routine examinations.

DISCUSSION

Intravenous aortography provides a safe and simple way of visualizing the aorta and its major branches. There is no need for premedication or general anesthesia. Complications due to direct aortic puncture and injection of concentrated opaque material are avoided. By the time the large amount of contrast material injected intravenously reaches the vital visceral arteries, it is well diluted with arterial blood. Repeat studies can be performed with ease. Another advantage is the ability to study a patient shortly after vascular surgery with no increased risk. Many of our intravenous aortographies have been done on an out-patient basis, thus avoiding the cost and inconvenience of hospitalization.

Because of the dilution of contrast in its

passage through the lesser circulation, delineation of the smaller vessels is not as detailed as in direct aortography. Fine changes in the smaller renal and mesenteric arteries are not clearly seen, nor are the distal branches of the celiac axis. However, in the majority of patients, the major arteries are well visualized and changes in caliber or flow can be clearly seen.

Toxic levels for rapid intravenous injection of contrast medium are not as yet fully established. Experimental studies are currently being carried out in dogs in an effort to determine the single massive dose safe levels and in addition to clarify the mechanism of death following this type of administration. A dose of 1 to 1.3 cc. of 85 to 90 per cent diatrizoate per kilogram of body weight has not proved injurious.

SUMMARY

A technique for performing aortography via the venous route has been presented. Two hundred and four aortograms have been made of 184 patients without death or serious complications. Information of diagnostic value was obtained in over 90 per cent of the cases. Aortic aneurysms, occlusions, renal lesions and postoperative aortic grafts have been studied by this method.

The technique is safe and simple. It avoids the complications of translumbar aortography secondary to direct puncture of the aorta.

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SERIAL FEMORAL ARTERIOGRAPHY IN OCCLUSIVE DISEASE*

CLINICAL-ROENTGENOLOGIC CONSIDERATIONS WITH A NEW CLASSIFICATION OF OCCLUSIVE PATTERNS

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FEMORAL arteriography has assumed in recent years a greater clinical and surgical significance, especially since the advent of arterial grafting for occlusive arterial disease.

Evaluation of the site and extent of segmental occlusion, the state of the distal arterial tree and the degree of collateral circulation can best be obtained by serialographic studies.

The purpose of this paper is: (1) to describe our technique of serial femoral arteriography with emphasis on its advantages; (2) to present a classification of the arteriographic patterns of occlusive arterial disease based on a survey of unselected patients; and (3) to interpret and evaluate the significance of the various arteriographic patterns.

Knowledge gained from such a study may offer a basis for a better understanding of the arterial hemodynamics in the occlusive process, shed some light on the mode of progression of the disease and help in the selection of the method of treatment to be applied.

BASIC CLINICOPATHOLOGIC DATA

In the lower extremity, the most frequent location of arteriosclerosis obliterans is currently believed to be the superficial femoral artery in Hunter's canal.[10,11,15] Leriche and Bertrand[10] noted it in 90 out of 133 instances of arterial occlusion of the lower extremity and Mavor[15] in 121 cases out of 142. The frequent involvement of the femoral artery in Hunter's canal is attributed to the unusual stress that this artery is subjected to by the unyielding walls of this aponeurotic tunnel. Lindbom's[11] roentgenologic and pathologic studies indicate that intimal thickening is initially most pronounced at the adductor magnus foramen. Whether or not mechanical factors play a significant part in this thickening is still a moot question, although some supportive experimental evidence has been advanced by Palma.[18] Since atheromata are found in many segments of the arterial tree, the mechanical stress factor could hardly be incriminated in all instances. However, at a point subjected to mechanical stress, subintimal bleeding may occur in an atheromatous plaque with secondary thrombosis. This may account for the frequent initial occlusion at the adductor magnus foramen. From this point, a thrombus may extend proximally toward the origin of the profunda femoris. Rarely does it propagate distally.

The second most frequent location of initial occlusion is the popliteal artery just above the knee joint. At this point the popliteal artery is subjected to similar trauma, though less severe than that of the femoral artery in Hunter's canal. The trauma occurs during movements of the joint, caused both by bending and stretching. The reported relative incidence of initial occlusion in this segment is much smaller (15 out of 133 by Leriche and Bertrand,[10] 16 out of 142 by Mavor[15]) than that of the superficial femoral artery.

Another location of initial lesions is in the tibial system, most commonly seen in

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patients over sixty years of age and in diabetics. There is little information about the relative incidence of this type of occlusion. Frequently, lesions of the popliteal or femoral arteries are associated with those of the tibial arteries.

Pathologically, arteriosclerosis affects primarily two arterial coats: the media and the intima. Medial arteriosclerosis (Mönckeberg's sclerosis) is characterized by the presence of calcification and necrosis. The calcific deposits are uniformly distributed, diffuse and fine-grained, and usually affect the entire circumference of the artery, involving all the major vessels of a given extremity. There is usually no occlusion of the lumen of the vessel. Intimal lesions are characterized by the atheromatous plaque deposits. As long as these plaques do not appreciably alter the size of the arterial lumen, their presence remains undetected clinically.[6,7] Growth of atheromata from the intima toward the center of the lumen may result in variable degrees of occlusion, ranging from mild stenosis to complete obliteration. Two additional pathologic processes usually accompany the development of the atheromatous plaque: calcification at its subintimal base, and thrombosis at its intraluminal surface. The former is irregularly distributed involving only a portion of the vascular wall in contrast to the medial calcification. Thrombosis most often completes the obliteration of the lumen. In contrast to the widespread nature of the intimal atheromatous lesions, the occlusive process in arteriosclerosis is often a segmental lesion. This fact is of great clinical and surgical significance. The widespread use of arteriography in recent years has been instrumental in establishing this fundamental feature of arteriosclerosis obliterans.

The incidence of segmental lesions among patients with occlusive disease has been variably estimated and ranges from 10 per cent[8] to 50 per cent.[2] This discrepancy is due to several factors, one of which may be the method of patient selection.

In the present study, based on an unselected group of patients with rather advanced arterial disease, we will attempt to (1) determine the incidence of patterns of arterial disease with regard to the site, extent and number of segmental occlusions and (2) correlate the groups of pre-existing collaterals with the various occlusion patterns.

TECHNIQUE OF FEMORAL ARTERIOGRAPHY

The single film exposure technique frequently fails to provide information concerning the entire arterial tree of the lower extremity. While serial automatic angiography has long been available for relatively small areas (cardiac, cerebral), roentgenographic equipment for arterial visualization of the extremities has remained rather inadequate. In recent years manually operated units permitting several exposures have been developed at a number of vascular disease and radiologic centers.[1,2,4,5,9,12,13,19,20,21,23] These long-segment serialographs are capable of providing a satisfactory angiogram with a single injection of contrast medium. With the use of manual units, however, several shortcomings exist; namely, the limited number of exposures, increased hazards of radiation and the unreliability inherent in the manual operation of the unit.

Full-length multifilm visualization is best secured by an automatic long-segment serialograph. Such a unit has been designed for the Radiology Division of Montefiore Hospital and its detailed description was previously reported.[22] This serialograph (Fig. 1 and 2, *A* and *B*) contains six 14×36 inch cassettes which can be serially exposed at predetermined intervals (Fig. 3) as selected on an interval timer control box. The interval between serial roentgenograms may be varied according to flow speed of the circulation from one second to twelve seconds. Each cassette holds two 14×17 inch sheets of film or a single 14×36 inch sheet. In order to compensate for the difference in thickness between the proximal and distal portions of the lower extremity, an aluminum wedge filter is placed

FIG. 1. Long segment serialograph with patient in position for femoral arteriography.

at the tube outlet. The resultant density of the roentgenogram is thus fairly uniform.

All femoral arteriographies have been performed by the percutaneous route. Food was withheld for several hours prior to the procedure. Premedication was administered to all cases consisting of a hypodermic injection of demerol hydrochloride (100 mg.), atropine sulfate (1/150 gr.) or phenergan hydrochloride (25 mg.) and seconal (100 mg.). The groin was shaved and prepared with zephiran solution. The field was draped with sterile towels and sterile gloves were worn.

Local infiltration anesthesia over the femoral area was used in some patients. Occasionally, we performed a prior intra-arterial injection of 10 cc. of 1 per cent procaine hydrochloride. The puncture of the femoral artery was performed with a No. 17 or 18 gauge spinal needle directed cephalad. Proximal compression of the artery was not considered necessary. A 20–25 inch plastic tube was interposed between the needle and the 30 cc. syringe, filled with the opaque substance. A two-way stopcock was attached to the tube on the syringe end.

The contrast medium used was 35 per cent iodopyracet (diodrast) in the early part of this series, while later 50 per cent sodium diatrizoate (hypaque) was used in

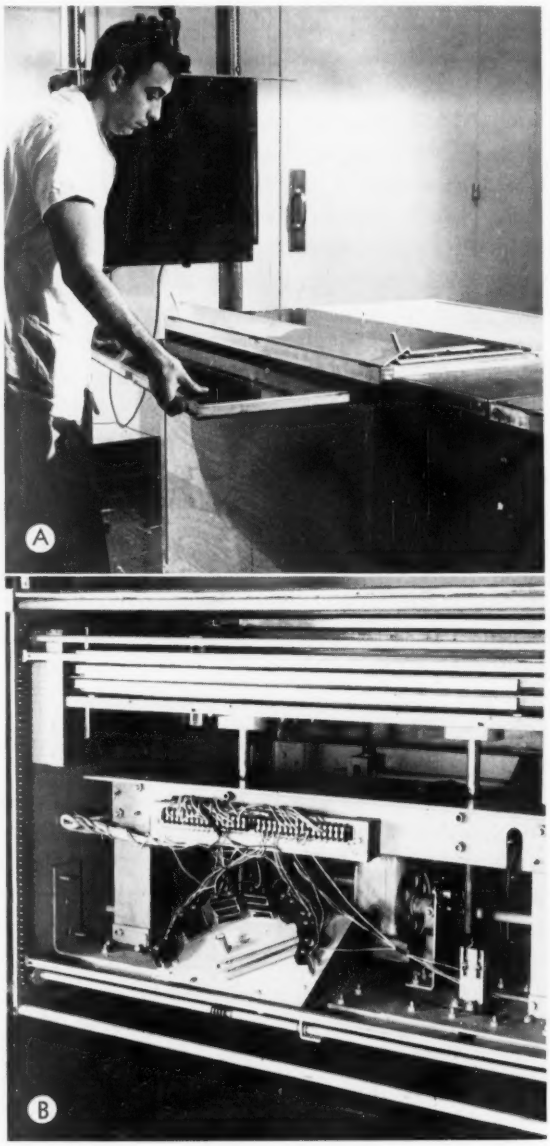

FIG. 2. (*A*) A 14×36 inch cassette is inserted into serialograph. (*B*) Interior of long-segment serialograph with side panel removed. The long cassettes are in position beneath the top surface of the unit.

the majority of the cases. An intravenous or intra-arterial sensitivity test was performed before each examination. There have been no significant allergic reactions in the entire group. A burning sensation from the groin down to the leg and foot was experienced by most patients. This discomfort was, however, minimized by adequate premedication and the intra-arterial injection of procaine. Following the removal of the needle, compression of the groin was maintained for five to ten minutes, in order to prevent any possible hematoma. Extravasation of medium occurred in 5 cases of the total series without untoward effect.

CLINICAL MATERIAL

This study is based on 102 consecutive femoral arteriograms of 91 patients. The age by decades and the sex incidence are shown in Table I. The age ranged from twenty-nine to eighty-seven years, with the majority of cases falling in the sixth and seventh decades. There were 64 males and 27 females. The presenting clinical manifestations were: intermittent claudication alone in 33 per cent of the cases; rest pain without trophic lesions in 22 per cent, rest pain associated with ulcers of the foot or leg in 17 per cent and gangrene in 28 per cent (Table II). In the

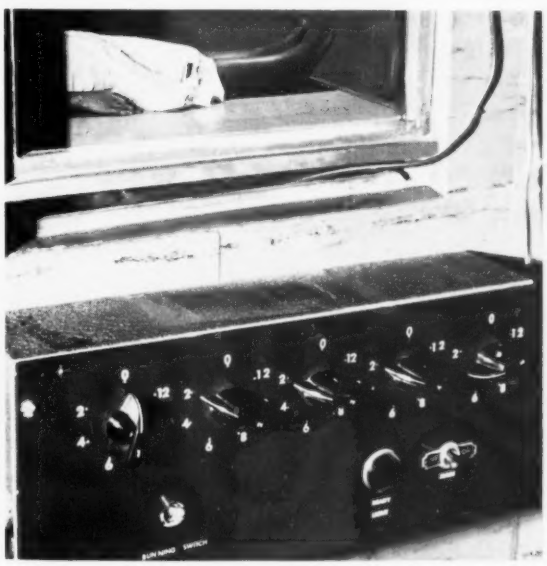

FIG. 3. Serialographic control panel showing the 5 intervals available during the exposure of the 6 roentgenograms. Each interval may be pre-set from one and one-half to twelve seconds. Patient lying on serialograph is seen through observation window.

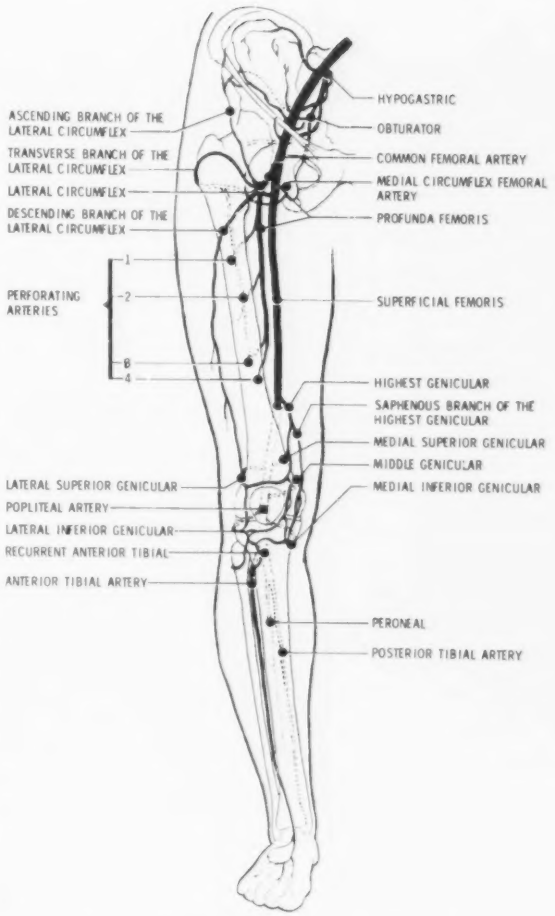

FIG. 4. Arteries of the lower extremity.

TABLE I

AGE AND SEX INCIDENCE

Age by Decades	Male	Female	Total
21–30	2	—	2
31–40	1	—	1
41–50	9	5	14
51–60	16	6	22
61–70	26	12	38
71–80	9	4	13
81–90	1	—	1
Total	64	27	91

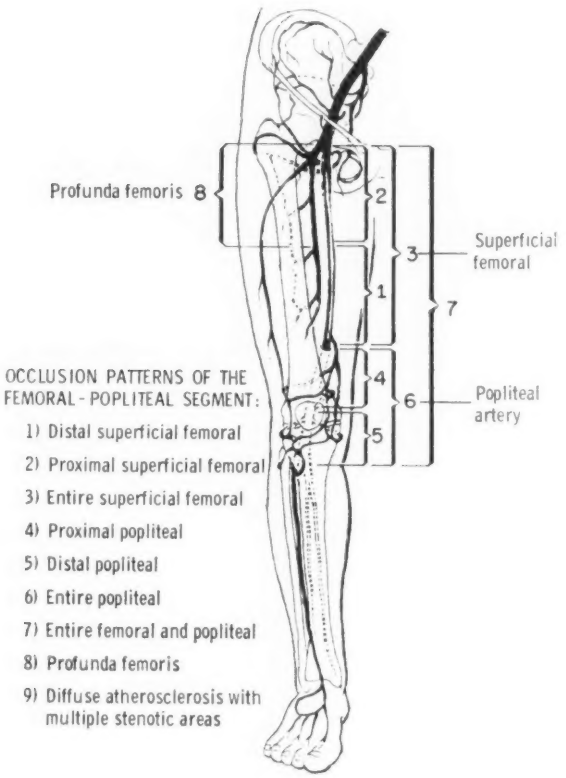

FIG. 5. Occlusion patterns of the femoral-popliteal segment.

FIG. 6. Occlusion Pattern 1. Filled-in segment represents site of occlusion of distal superficial femoral artery.

group of patients with rest pain associated with ulcers and gangrene, 28 of 46 were arteriosclerotic diabetics. The presence of rest pain with and without trophic changes in approximately two-thirds of the patients reflects advanced arterial insufficiency in this series. The nature of the occlusive arterial disease was: arteriosclerosis obliterans in 59 (58 per cent), arteriosclerosis obliterans in diabetics in 37 (36 per cent), thromboangiitis obliterans (Buerger's disease) in 4 (4 per cent) and embolism in 2 (2 per cent). There were twice as many fe-

TABLE II

CLINICAL MANIFESTATIONS

Clinical Manifestations	Arteriosclerosis Obliterans	Arteriosclerosis Obliterans and Diabetes	Other	
			Thromboangiitis Obliterans	and Embolism
Intermittent Claudication	31	2	1	
Rest Pain				
No Trophic Changes	12	7	3	
Ulcers	7	9	1	
Gangrene	9	19	1	
Total	59	37	6	

male patients in the diabetic group (43 per cent) as in the nondiabetic group (21 per cent).

ARTERIOGRAPHIC FINDINGS

For a better appreciation of the anatomopathologic findings to be described, the normal arterial roentgen anatomy of the lower extremity is shown in Figure 4.

1. CLASSIFICATION OF ARTERIOGRAPHIC PATTERNS OF OCCLUSIVE DISEASE

A. *Femoral-Popliteal Segment.* In order to facilitate an evaluation of the occlusive disease in the femoral-popliteal segment, a classification was adopted based upon the location and extent of the occlusion. Nine patterns emerged from this classification. Each femoral arteriogram was given a classification number. In 68 instances a single number was used, while in 33 cases it was necessary to use 2, and in one instance 3 numbers to adequately describe the combined occlusive lesions. The classification of arterial disease in the femoral-popliteal segment into 9 patterns and their relative incidence in nondiabetic and diabetic patients are shown in Table III. These occlusion patterns are illustrated diagrammatically in Figures 5 through 14. Arteriograms of each pattern are shown in Figures 15 through 23. Figures 24 through 26 are examples of combinations of occlusion patterns.

The total combined incidence of the first 3 patterns of femoral occlusions was 36.4 per cent and that of the next three patterns (popliteal occlusion) was 32.7 per cent. These findings are at variance with the commonly accepted higher incidence of femoral artery occlusion as compared with

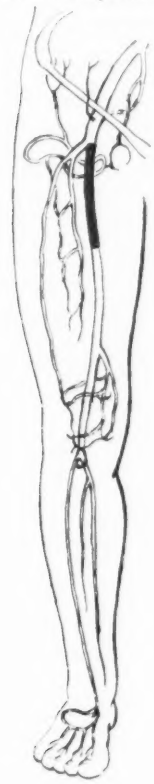

FIG. 7. Occlusion Pattern 2. Filled-in segment represents occlusion of proximal superficial femoral artery.

FIG. 8. Occlusion Pattern 3. Filled-in segment represents occlusion of entire superficial femoral artery.

FIG. 9. Occlusion Pattern 4. Filled-in segment represents occlusion of proximal popliteal artery.

FIG. 10. Occlusion Pattern 5. Filled-in segment represents occlusion of distal popliteal artery.

TABLE III

CLASSIFICATION OF ARTERIOGRAPHIC PATTERNS OF OCCLUSION DISEASE OF THE FEMORAL-POPLITEAL SEGMENT

Pattern	Site and Extent of Occlusion	Nondiabetic		Diabetic		Total	
		No.	Per Cent	No.	Per Cent	No.	Per Cent
1	Distal Superficial Femoral Artery	10	12.8	14	23.7	24	17.5
2	Proximal Superficial Femoral Artery	4	5.1	1	1.7	5	3.6
3	Entire Superficial Femoral Artery	16	20.4	5	8.5	21	15.2
4	Proximal Popliteal Artery	12	15.5	10	17.0	22	16.0
5	Distal Popliteal Artery	5	6.4	4	6.7	9	6.5
6	Entire Popliteal Artery	5	6.4	9	15.1	14	10.2
7	Entire Femoral and Popliteal Artery	10	12.8	4	6.7	14	10.2
8	Profunda Femoris Artery	4	5.1	7	11.8	11	8.0
9	Diffuse Atherosclerosis. No Occlusion	12	15.5	5	8.8	17	12.7
Total		*78*	*100*	*59*	*100*	*137*	*100*

that of the popliteal artery (Table IV). The difference in incidence may be due to the high percentage of diabetic and advanced arterial disease patients encountered in our series when compared with the published reports. The proximal superficial femoral artery was much less frequently involved than the distal segment. This finding is in agreement with the concept that the initial location of the occlusion is at the adductor magnus opening. In contrast to the femoral artery, the proximal popliteal artery was more frequently involved than the distal segment. The reason may be related to the mechanical stress to which it is subjected during the motion of the knee joint and its close anatomic relationship with the surface of the femur.

The entire superficial femoral and the entire femoral-popliteal segment are more often occluded in arteriosclerotic nondiabetic patients than in diabetics.*

FIG. 11. Occlusion Pattern 6. Filled-in segment represents occlusion of entire popliteal artery.

FIG. 12. Occlusion Pattern 7. Filled-in segment represents occlusion of entire femoral-popliteal segment.

Occulsion of the entire popliteal artery is more frequently seen in diabetics. The profunda femoris, whose important role as a main collateral channel is well known, is rarely involved by the occlusive process, a fact noted by Lindbom[11] (4 out of 108 cases) and others. Mavor[15] in his series of 104 cases found it free of disease in all instances. In our series, as in that of Margulis *et al.*,[14] occlusion of the profunda femoris artery was surprisingly high (8 per cent) with a preponderance in diabetic patients.

In 12.7 per cent the femoral-popliteal

* When the figures in Table III are subjected to statistical analysis, there is only a biometrically significant difference between diabetics and nondiabetics in Pattern 3.

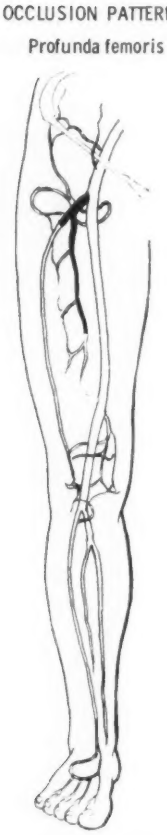

FIG. 13. Occlusion Pattern 8. Filled-in segment represents occlusion of the profunda femoris artery.

segment displayed diffuse atherosclerosis, characterized by varying degrees of narrowing of the lumen. The artery usually appeared slightly tortuous with multiple areas of stenosis. In most cases there were associated lesions of the tibial vessels with involvement varying from minimal to marked. In 4 cases all three leg vessels were visualized, in 4 one or two leg vessels were occluded, in 8 only collaterals were visualized and in 1 no visualization of vessels was obtained. In addition, in 3 instances there was an associated occlusion of the distal popliteal artery. Combined occlusion patterns were demonstrated in 34 of the 102 arteriograms (Table v). In about one-half of the arteriograms, distal superficial femoral artery occlusion was noted to be associated with other occlusion patterns. In all of these cases but one, only two patterns were combined. In the case with three patterns, the occlusive process affected the distal superficial femoral artery, the proximal popliteal artery and the profunda femoris segments. In addition, the leg arteries were also involved to a marked degree.

TABLE IV

INCIDENCE OF SUPERFICIAL FEMORAL AND POPLITEAL ARTERY OCCLUSION

Authors	Per Cent	
	Femoral Artery	Popliteal Artery
Milanes *et al.*[16] 1953	40.0	13.0
Margulis *et al.*[14] 1957	59.0	29.0
Mavor[15] 1956	85.0	11.0
Haimovici, Shapiro and Jacobson 1959	36.4	32.7

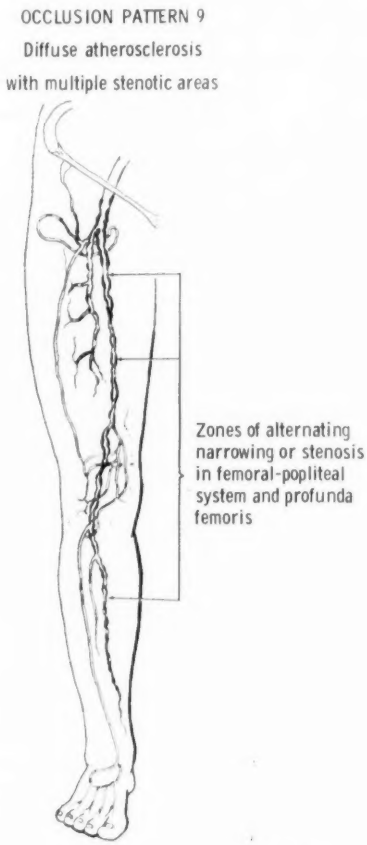
OCCLUSION PATTERN 9
Diffuse atherosclerosis
with multiple stenotic areas
Zones of alternating narrowing or stenosis in femoral-popliteal system and profunda femoris

FIG. 14. Occlusion Pattern 9. Diffuse atherosclerosis with multiple stenotic areas.

TABLE V

FREQUENCY OF COMBINED OCCLUSION ARTERIOGRAPHIC PATTERNS

Combined Patterns	Diabetic	Nondiabetic	Total
Distal Superficial Femoral and Proximal Popliteal Artery (1+4)	5	1	6
Distal Superficial Femoral and Distal Popliteal Artery (1+5)	—	1	1
Distal Superficial Femoral and Entire Popliteral Artery (1+6)	4	1	5
Distal Superficial Femoral and Profunda Femoris Artery (1+8)	3	—	3
Distal Superficial Femoral and Distal Popliteal and Profunda Femoris Artery (1+5+8)	—	1	1
Proximal Superficial Femoral and Proximal Popliteal Artery (2+4)	—	1	1
Proximal Superficial Femoral and Profunda Femoris Artery (2+8)	1	—	1
Entire Superficial Femoral and Proximal Popliteal Artery (3+4)	3	4	7
Entire Superficial Femoral and Profunda Femoris Artery (3+8)	1	—	1
Distal Popliteal Artery and Diffuse Atherosclerosis (5+9)	2	1	3
Entire Popliteal and Profunda Femoris Artery (6+8)	—	1	1
Entire Femoral-Popliteal and Profunda Femoris Artery (7+8)	2	2	4
Total	*21* (61.8%)	*13* (38.2%)	*34*

Table v shows that 61.8 per cent of the combined occlusive patterns occurred in diabetics.

Run-off. The "run-off" represents the patent major distal vessel below the site of segmental occlusion. This vascular channel is fed by a varying number of collaterals. The presence of an adequate outflow or "run-off" is the most decisive factor in the selection of patients for arterial grafting or thrombo-endarterectomy. Patients having a complete block of the distal popliteal artery and its bifurcation are generally not suitable for such procedures. With this problem in mind, evaluation of the run-off was done only in the patients displaying an open distal popliteal artery and its bifurcation. (Patterns 1, 2, 3 and 4, singly or in combination, were used.) One-half of the cases in this series met this prerequisite. In this group, 33 were arteriosclerotic nondiabetics and 18 arteriosclerotic diabetics. The "run-off" was graded as good, fair or poor, according to the degree of atherosclerotic involvement of the major distal vessel. Table VI summarizes these findings. A good "run-off" was about three times as frequent in the arteriosclerotic nondiabetic patients when compared with the diabetic, and conversely, a poor "run-off" was twice as frequent in the diabetic when compared with the nondiabetic group.

B. *Leg Vessels.* Of the 102 femoral arteriograms, good visualization of the leg

TABLE VI

DEGREE OF RUN-OFF

Degree of Run-Off	Arteriosclerosis Obliterans Nondiabetic		Arteriosclerosis Obliterans Diabetic	
	No.	Per Cent	No.	Per Cent
Good	15	45.5	3	16.6
Fair	12	36.3	8	44.4
Poor	6	18.2	7	39.0
Total	*33*	*100*	*18*	*100*

FIG. 15. Occlusion of distal superficial femoral artery (Pattern 1). Note numerous collaterals bridging defect. Good "run-off."

FIG. 16. Occlusion of proximal superficial artery (Pattern 2).

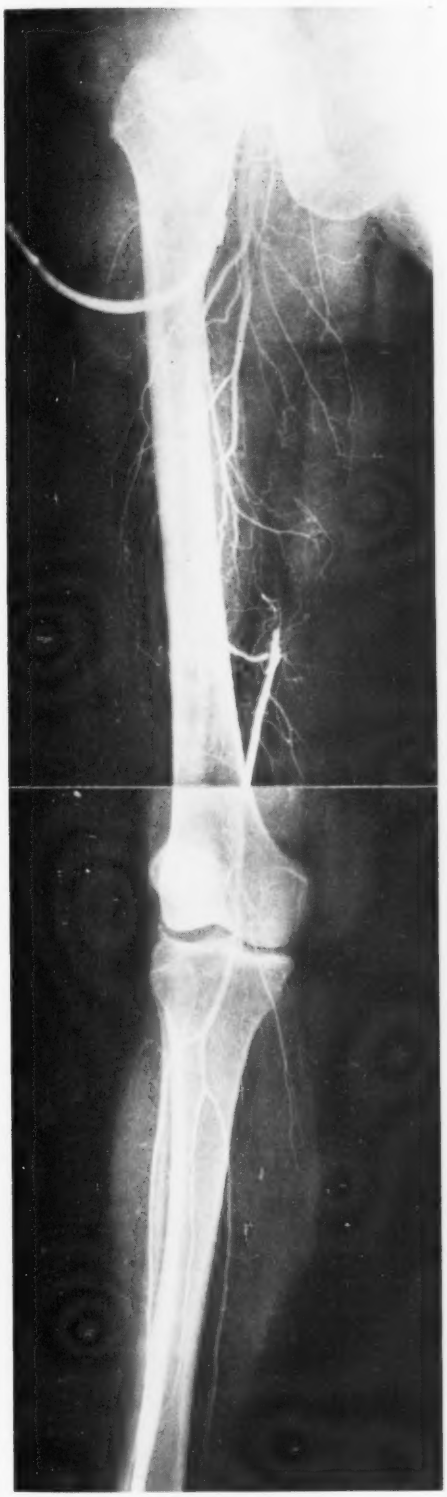

Fig. 17. Occlusion of entire superficial femoral artery (Pattern 3). Good "run-off."

Fig. 18. Occlusion of proximal popliteal artery (Pattern 4). Abundant collaterals with fair "run-off."

FIG. 19. Occlusion of distal popliteal artery (Pattern 5). Sparse collaterals with fair "run-off."

FIG. 20. Occlusion of entire popliteal artery (Pattern 6). "Run-off" poor.

FIG. 21. Occlusion of entire femoral-popliteal segment (Pattern 7). Numerous collaterals. No "run-off."

FIG. 22. Occlusion of profunda femoris artery (Pattern 8). Multiple occlusions of lower femoral-popliteal segment.

FIG. 23. Diffuse atherosclerosis with multiple stenotic zones (Pattern 9).

FIG. 24. Occlusion of lower superficial femoral and proximal popliteal arteries (Patterns 1 and 4).

Fig. 25. Occlusion of entire superficial femoral and proximal popliteal arteries (Patterns 3 and 4).

Fig. 26. Occlusion of lower superficial femoral and entire popliteal arteries due to embolus (Patterns 1 and 6).

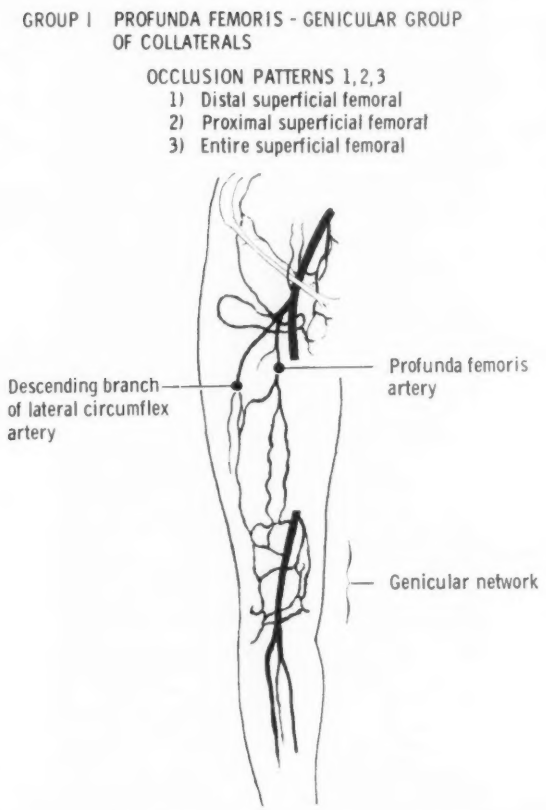
GROUP I PROFUNDA FEMORIS - GENICULAR GROUP OF COLLATERALS
OCCLUSION PATTERNS 1, 2, 3
1) Distal superficial femoral
2) Proximal superficial femoral
3) Entire superficial femoral
Descending branch of lateral circumflex artery
Profunda femoris artery
Genicular network

FIG. 27. Collaterals of profunda femoris-genicular group seen in occlusion Patterns 1, 2 and 3.

arteries was demonstrated in 86. In 70 (81.4 per cent) there was seen an associated involvement of the femoral-popliteal segment, and in 3 instances the distal popliteal artery was blocked. In the remaining 13 (15.1 per cent), the leg arteries alone were the site of the occlusive process, although the femoral-popliteal segment displayed diffuse atherosclerosis (Pattern 9, Table III). The distribution of the involvement of the three major leg arteries is shown in Table VII. The involvement was graded according to the patency of the major arteries and the number and size of collaterals. From these data it appears clearly that the incidence of involvement of the leg arteries is much higher in diabetics when compared with the nondiabetics.

2. COLLATERALS

The collaterals found in the various occlusion patterns of the femoral-popliteal segment may be classified into three major groups (Table VIII).

I. *Profunda Femoris-Genicular Group.* In the occlusion of the superficial femoral artery (Patterns 1, 2 and 3), collaterals which bypass the arterial defect originate from one or more branches of the profunda femoris and anastomose with branches of the genicular systems (Fig. 27). The branches of the profunda femoris most frequently assuming the role of major collaterals noted in our series were: (a) the descending branch of the lateral circumflex or the rectus femoris collateral and (b) the perforating branches, mostly the third and fourth. The branches of the genicular system most concerned in the anastomosis with the above collaterals originate either from the highest genicular or lateral su-

TABLE VII

DISTRIBUTION OF INVOLVEMENT OF MAJOR LEG ARTERIES, IN 86 CASES

Degree of Involvement	Arteriosclerosis Obliterans Nondiabetic		Arteriosclerosis Obliterans Diabetic	
	No.	Per Cent	No.	Per Cent
Group 1				
All 3 Arteries Patent	15	27.4	1	3.3
Group 2				
One or 2 Arteries Occluded	20	36.3	13	41.9
Group 3				
All 3 Arteries Occluded	20	36.3	17	54.8
Total	*55*	*100*	*31*	*100*

perior genicular artery. In complete occlusion of the superficial femoral artery, anastomoses between the obturator and superior gluteal arteries along with the lateral and medial femoral circumflex arteries supply the important link between the internal iliac and profunda femoris arteries.

II. *Genicular-Tibial Group.* In occlusion of the popliteal artery (Patterns 4, 5 and 6), the major collaterals arise from: (1) the highest genicular artery with its musculoarticular and saphenous branches and (2) the profunda femoris artery with its fourth perforating branch and the descending branch of the lateral femoral circumflex. These collaterals anastomose with the genicular arteries and, via this network, with the recurrent tibial arteries (Fig. 28). About half of our cases belonged to this genicular-tibial group. While the number and size of the collaterals varied with the occlusion pattern, the saphenous branch of the highest genicular artery, the descending branch of the lateral circumflex artery and the fourth perforating branch were the most developed and constant collaterals in this series.

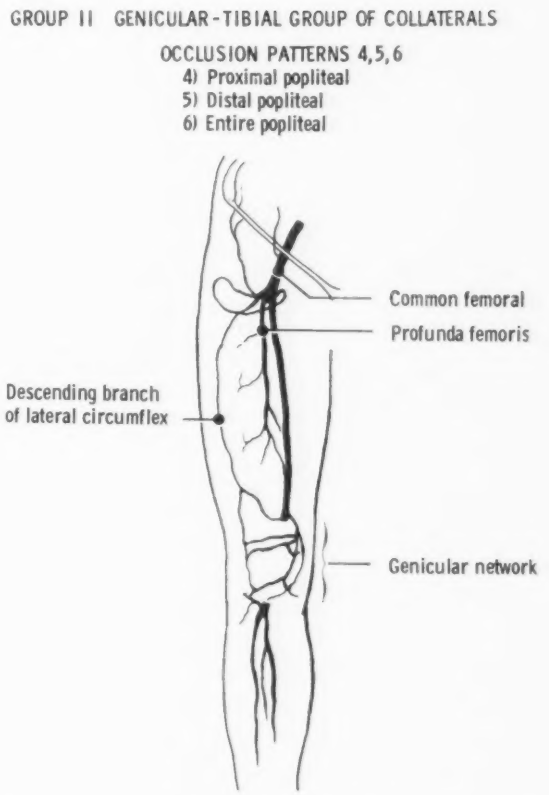

Fig. 28. Collaterals of genicular-tibial group seen in occlusion Patterns 4, 5, and 6.

III. *Profunda Femoris-Genicular-Tibial Group.* In combined occlusion of the superficial femoral and popliteal artery (Pattern 7), collaterals from the profunda femoris artery anastomose with branches of the genicular network which in turn anastomose with branches of the tibial arteries. In this group, as in Group 1, the profunda femoris receives anastomotic

Table VIII

Distribution of Groups of Collaterals According to Occlusion Patterns of the Femoral-Popliteal Segment*

Collaterals	Arteriosclerosis Obliterans		Arteriosclerosis Obliterans and Diabetes		Total	
	No.	Per Cent	No.	Per Cent	No.	Per Cent
I. Profunda Femoris-Genicular Group (Patterns 1, 2 and 3)	21	39.6	9	25.7	30	34.1
II. Genicular-Tibial Group (Patterns 4, 5 and 6)	22	41.5	23	65.7	45	51.1
III. Profunda Femoris-Genicular-Tibial Group (Pattern 7)	10	18.9	3	8.6	13	14.8
Total	*53*	*100*	*35*	*100*	*88*	*100*

* Evaluation of collaterals based on 88 of the 102 arteriograms.

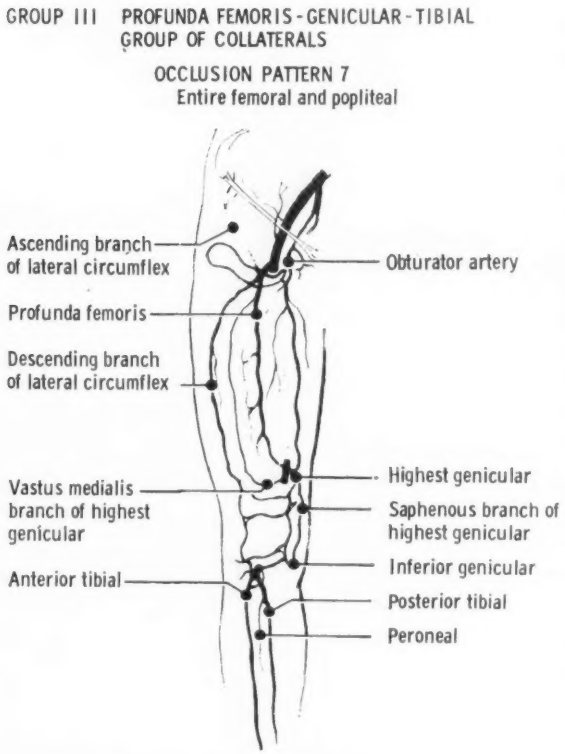

FIG. 29. Collaterals of profunda femoris-genicular-tibial group seen in occlusion Pattern 7.

branches from the internal iliac artery (Fig. 29). Only 14.8 per cent of cases belonged to this group and of these the majority was in arteriosclerotic nondiabetics.

In the group of patients with involvement of the leg arteries, the origin, distribution and anastomosis of their collaterals were not as well outlined as in the foregoing three groups. Serial arteriography which includes the entire leg and foot is necessary for adequate evaluation of this group of collaterals. Such an investigation is now in progress.

Degree of Collaterals. The efficiency of collateral circulation can be determined by: (a) the number and size of collaterals, (b) the extent of occlusion of the major artery, and (c) the presence of a re-entry into the main arterial channel. With these criteria in mind, the degree of collaterals was classified into good, fair, and poor (Table IX). The incidence of good collaterals is slightly higher in arteriosclerotics when compared with diabetics.

Comparison of the degree of "run-off" (Table VI) with that of the collaterals (Table IX) indicates a good correlation between these two components in arteriosclerosis obliterans and an inverse relationship in arteriosclerosis with diabetes. One of the reasons for this inverse relationship may be due to the higher incidence of popliteal occlusion with poor or absent "run-off" in diabetics.

3. CALCIFICATION

By far the most common form of calcification encountered was that of the intimal type. Arterial calcification was graded as slight, moderate or marked. Roentgenograms failed to show any degree of calcification in 38.5 per cent of the arteriosclerotic patients and in 13.8 per cent of the diabetic patients. In contrast, moderate to marked calcification was found in 42 per cent diabetics as compared with 26 per cent nondiabetics (Table X).

TABLE IX

DEGREE OF COLLATERALS, ALL GROUPS

Degree	Arteriosclerosis Obliterans		Arteriosclerosis Obliterans and Diabetes		Total	
	No.	Per Cent	No.	Per Cent	No.	Per Cent
Good	31	49.2	14	38.8	45	45.4
Fair	19	30.1	12	33.3	31	31.3
Poor	13	20.7	10	27.9	23	23.3
Total	*63*	*100*	*36*	*100*	*99*	*100*

Table X

DEGREE OF CALCIFICATION CORRELATED WITH THE OCCLUSION DISEASE

Degree of Calcification	Arteriosclerosis Obliterans		Arteriosclerosis Obliterans and Diabetes	
	No.	Per Cent	No.	Per Cent
None	22	38.5	5	13.8
Slight	20	35.1	16	44.4
Moderate	5	8.8	7	19.5
Marked	10	17.6	8	22.3
Total	57	100.0	36	100.0

PROGNOSTIC CONSIDERATIONS

Prognosis for an extremity with occlusive arterial disease depends on many factors, both general and local. Of the general factors, diabetes plays a predominant role. In diabetics, arteriosclerosis is more diffuse and involves more often the distal arteries of the leg. Infection, when present, is a serious complication. Table II indicates the clinical manifestations to be more pronounced in diabetics than in nondiabetics. The incidence of combined occlusion patterns, of poor "run-offs," of leg artery involvement, and of poor collaterals is much higher in diabetics, as shown in Tables V, VI, VII and IX.

Of the local factors, the pattern of occlusion and tne degree of compensatory collateral circulation are decisive. It is generally difficult to assess the prognosis in a given occlusion pattern. However, the overall clinical and arteriographic correlation shows that prognosis in cases of superficial femoral artery occlusion (Patterns 1, 2 and 3) is much better than in cases of popliteal artery occlusion (Patterns 4, 5 and 6). A combination of two or more occlusion patterns, particularly if the popliteal artery is involved, further aggravates the prognosis. Furthermore, occlusion of leg arteries associated with any occlusion pattern of the femoral-popliteal segment will materially reduce the terminal arterial flow and thus will lead to gangrene.

In our series of 102 arteriograms, 18 patients had amputations: 5 transmetatarsal, 8 midleg and 5 midthigh. The site of occlusion in the 18 cases was: femoral artery 3, popliteal artery 13, leg arteries 2. One-half of these patients had two or three occlusion patterns, the popliteal artery being involved in each of them. Of the 16 cases with femoral-popliteal artery occlusion patterns, 12 additionally exhibited occlusion of the three major leg arteries. Ten of the 18 patients, were diabetics. In 16 of the 18 cases, gangrene was present when arteriography was performed. In 14 cases, the arteriographic findings confirmed the poor clinical prognosis. In the remaining 4 cases, exhibiting fair "run-off" and adequate collaterals, superimposed infection and iliac artery occlusion led to gangrene.

Thus, in most instances a good correlation existed between the clinical and angiographic findings, attesting to the reliability of serial arteriography.

SUMMARY

1. An analysis of the results of 102 femoral arteriograms of 91 patients is presented.

2. The practical value of long-segment serial femoral arteriography is emphasized and a new unit is described.

3. A classification of occlusive disease in the femoral-popliteal system into 9 arteriographic patterns is presented.

4. The importance of the "run-off" in the selection of patients for arterial grafting is emphasized.

5. A classification of collaterals into three groups according to occlusion patterns of the femoral-popliteal segment is given.

6. Prognostic considerations based on arteriographic patterns and degree of collaterals are arrived at by correlating them with clinical findings.

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IDENTIFICATION OF PELVIC MASSES BY PHLEBOLITH DISPLACEMENT*

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FROM the early days of radiology to the present, pelvic phleboliths have been regarded as undesirable objects which made the identification of ureteral calculi more difficult. Occasionally, the presence of phleboliths has aided the diagnosis of angiomatous malformations. The use of pelvic venography has proved a valuable diagnostic method in localization of pelvic tumors. It is surprising, therefore, that these common calcified structures with a rather constant anatomic distribution have not been employed for detection of expanding pelvic masses.

Phleboliths are calcified thrombi which are attached to the wall of a vein by a thin pedicle or "tail."[2] They are present in about one-third or one-fourth of all adult pelves, the number increasing with age. Thus, phleboliths are most frequently present in older patients who are also most likely to develop pelvic masses. The number of

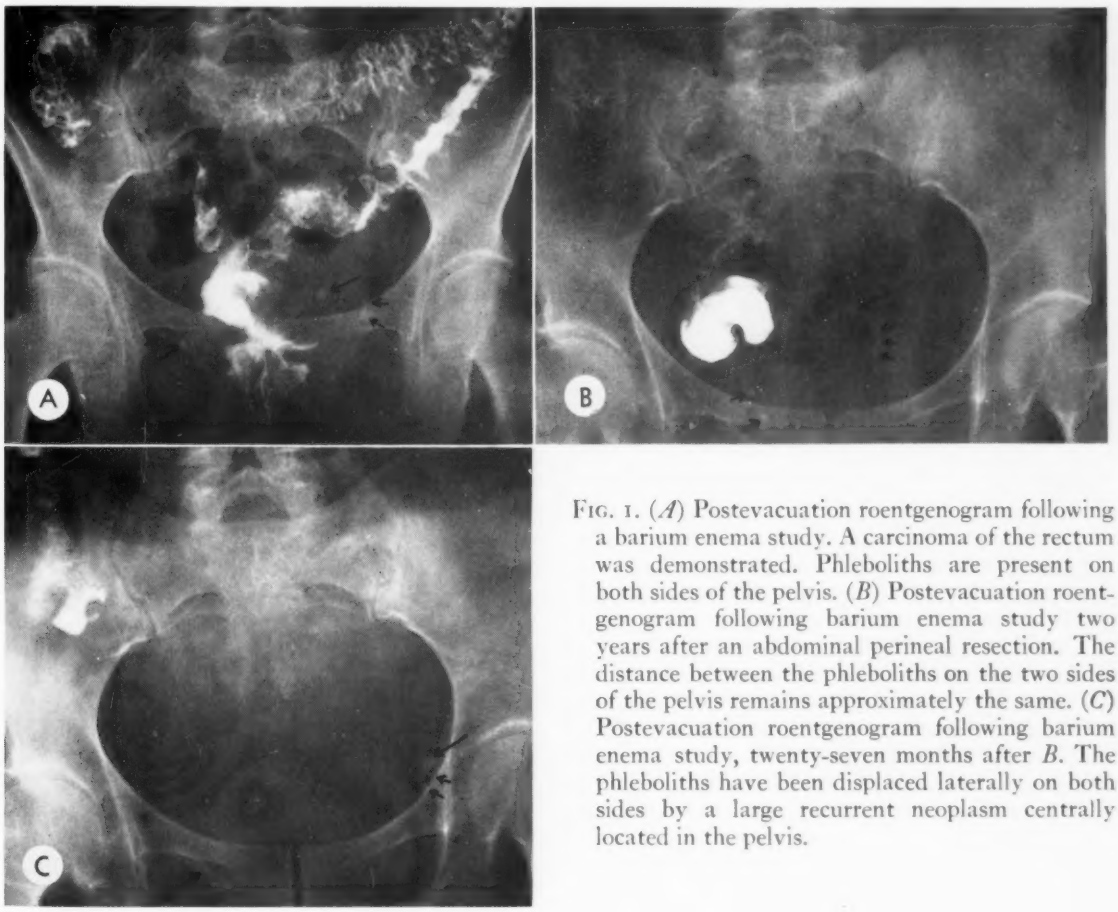

FIG. 1. (*A*) Postevacuation roentgenogram following a barium enema study. A carcinoma of the rectum was demonstrated. Phleboliths are present on both sides of the pelvis. (*B*) Postevacuation roentgenogram following barium enema study two years after an abdominal perineal resection. The distance between the phleboliths on the two sides of the pelvis remains approximately the same. (*C*) Postevacuation roentgenogram following barium enema study, twenty-seven months after *B*. The phleboliths have been displaced laterally on both sides by a large recurrent neoplasm centrally located in the pelvis.

* From the Department of Radiology, University of California, School of Medicine, San Francisco, California.

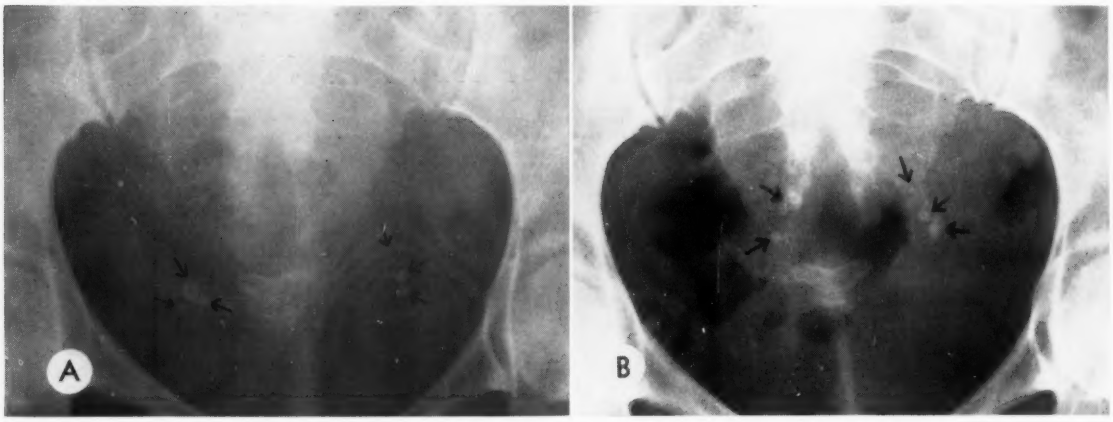

FIG. 2. (*A*) Patient who has had an abdominal perineal resection for carcinoma of the rectum. (*B*) Roentgenogram obtained one and one-half years after *A*. The phleboliths have been displaced medially and superiorly by extensive pelvic metastases.

phleboliths in a pelvis may vary from one to 24, or more, but in four-fifths of all cases, is less than four. They are slightly more numerous in females than males.[1] They are present in the rectal and vesical venous plexuses of both sexes and in the broad ligament of the female and the prostatic venous plexus of the male.

On roentgenograms of the pelvis, the distribution of phleboliths differs somewhat in the two sexes. In males they lie for the most part adjacent to the linea terminalis and in the lower part of the pelvis. The distribution in females is more diffuse because of the presence of phleboliths in the broad ligaments.[1] The phleboliths in the broad ligaments, vesical and rectal plexuses may change position slightly with distention and emptying of the bladder and rectum. With stereoscopic anterioposterior roentgeno-

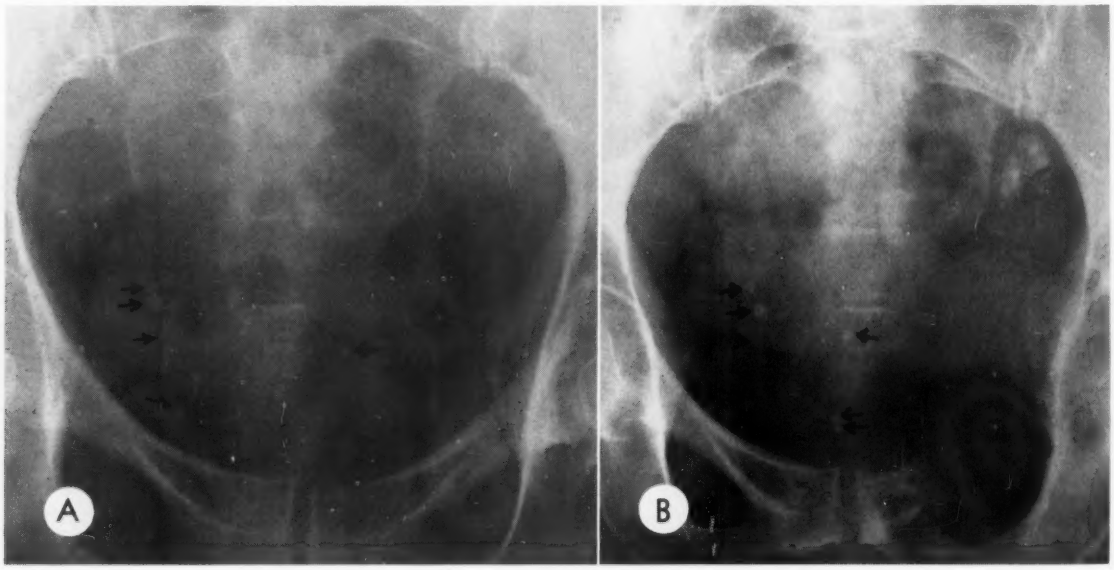

FIG. 3. (*A*) Soft tissue mass in the left side of the pelvis diagnosed previously on biopsy as undifferentiated epidermoid carcinoma. The upper border of the mass is calcified and there is bone destruction of the medial wall of the left ilium. The phleboliths of the left side of the pelvis have been displaced medially. (*B*) Roentgenogram obtained four and one-half years after *A*. The mass has increased considerably in size and has displaced the phleboliths previously located on the left side, to the right of midline.

grams, the position of the phleboliths can be determined more accurately. Thus, the prostatic and vesical plexuses can be seen anteriorly, the plexuses of the broad ligaments are located higher and in midpelvis, and the rectal plexuses are seen posteriorly.

We have observed several patients in whom pelvic masses have produced displacement of phleboliths. In most cases the mass was identified on plain roentgenograms, but in some instances the displaced phleboliths were the only roentgenologic manifestation. Two patients had abdominal perineal resections, and enemas to demonstrate the pelvic viscera could not be performed. In other patients, the response to roentgen therapy or surgical removal of a mass could be judged by a migration of the phleboliths toward their normal anatomic position. As expected, midline masses displaced the phleboliths laterally and produced an increased distance between the phleboliths on both sides of the pelvis. Lateral pelvic masses have displaced the phleboliths medially. The phleboliths were also displaced superiorly or inferiorly depending upon the position of the mass (Fig. 1 through 5). The phleboliths initially affected have been those nearest the expanding lesion.

Fig. 4. Carcinoma of the cervix treated by irradiation three years previously. At the time the roentgenogram was obtained a mass was palpable in the left lower quadrant of the abdomen. The left kidney did not function. The phleboliths of the left side of the pelvis have been displaced medially. The rectum, filled with feces, has not been displaced or deformed.

It is believed that more detailed informa-

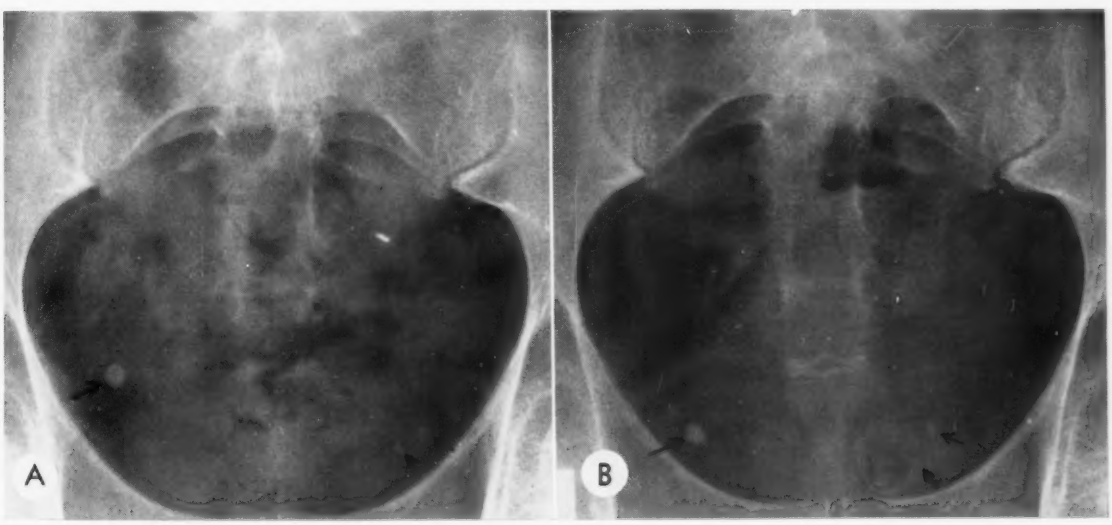

Fig. 5. (*A*) Patient with transitional cell carcinoma of the bladder. The distance between the phleboliths of the two sides of the pelvis is 9 cm. (*B*) Same patient after partial cystectomy. Removal of the bladder and extensive tumor caused phleboliths to move toward the midline. The distance between the phleboliths is 6.5 cm.

tion concerning the position and variability of phleboliths on stereoscopic roentgenograms would contribute to the earlier detection and localization of pelvic masses.

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SOME ASPECTS OF CINE- AND HIGH SPEED SERIAL ANGIOGRAPHIC TECHNIQUES*

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ALTHOUGH angiocardiography is now a well accepted diagnostic method, there remains considerable difference of opinion regarding the best technique for recording the roentgen data. In general, advocates of angiocardiography are divided between cineroentgenographic and high speed serialographic techniques as the method of choice. The availability of both techniques in the Department of Radiology of the University of Missouri has permitted us to attempt to clarify some of the problems relating to these two modalities.

This investigation was directed toward three broad aspects of the problem: I, dosimetry; II, relative diagnostic effectiveness; and III, evaluation of the relative roentgen opacities of various concentrations of contrast media.

I. DOSIMETRY

In both cine- and serial angiocardiography, the hazard of excessive radiation is very real, particularly since these patients have usually been subjected to considerable fluoroscopic and roentgenographic exposure prior to angiocardiography. This portion of the investigation is concerned with the magnitude of the radiation exposure of the patient and of the attendant personnel which is inherent in angiocardiography.

Direct radiation measurements were made utilizing a phantom constructed with a human skeleton without extremities. Paraffin of a density 0.89 was molded to human form to substitute for tissue. The lungs were simulated by sponge rubber and the mediastinum by paraffin. The anteroposterior measurement of the thoracic cage phantom was 23 cm. To bring the unit density closer to 1.0, a shield of copper, 0.2 mm. in thickness, was added to the surface of the phantom. This total phantom, by roentgenographic testing, was representative of the physical conditions in an average sized human.

Surface radiation doses were recorded with a Victoreen Model 70 condenser r-meter with 1 and 5 r chambers. Gonadal doses and doses to attendant personnel were recorded with Victoreen pocket dosimeters Model 362, which have a range of 0 to 0.2 r.

SKIN DOSES

A. *Serial Roentgenography.* Skin dose measurements were made using biplane Schönander serialographic cameras, two 500 ma. Picker diagnostic generators with dynapulse timing, and target film distance of 32 inches (target skin distance 21 inches). The dynapulse modification increases the capacity of the 500 ma. generators to 1,200 ma., with timing variable from 1 to 5 milliseconds. The field size at film level was 13 by 13 inches. The field size on the skin was 8.5 by 8.5 inches. Operative factors were 100 kv., 1,000 ma., 3 mm. aluminum filter added. The beam was collimated with a Picker roentgenographic collimator with double lead diaphragm.

The dosimeter was placed on the surface of the phantom in the center of the anterior field. In each test 30 exposures were made with varying film speeds and exposure times.

A similar series of experiments was performed with the dosimeter in the center of

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TABLE I

INFLUENCE OF VARYING EXPOSURE TIME ON SKIN DOSE IN SERIAL ROENTGENOGRAPHY*

Exposure Time in Milliseconds	Total r per Examination
1	.96
2	1.97
3	2.73
4	3.40
5	4.05

* 30 film series at 1½ films per second.

TABLE II

INFLUENCE OF VARYING EXPOSURE RATE ON SKIN DOSE IN SERIAL ROENTGENOGRAPHY*

Exposure Time in Milliseconds	Film Rate in Films/Second	Total r per Examination
1	1.5	.96
1	6.0	.93
2	1.5	1.97
2	6.0	1.90
3	1.5	2.73
3	6.0	2.62
4	1.5	3.40
4	6.0	3.20
5	1.5	4.05
5	6.0	3.84

* 30 film series.

the lateral field and using the lateral camera. The technique employed was identical to that used in the anteroposterior plane, except that the target skin distance was 16.5 inches, and the skin field size was 6.5 by 6.5 inches.

In order to record the total radiation dose to each field, a dosimeter was also placed in the center of the right angle field to record the contribution of scatter.

The effect on skin dosage of varying the exposure time is shown in Table I. It appears from these data that the skin dose does not follow the increasing exposure time in a linear fashion. This discrepancy becomes more apparent with increasing exposure times. Perhaps this nonlinearity may be related to a greater fall-off in pulse height with the longer exposures.

The effect on dosage of varying the exposure rate is shown in Table II. In this experiment each millisecond exposure time was tested with the slowest and fastest camera speeds. The data presented indicate that at faster camera speeds there is a consistent slight diminution in total dose. However, for practical purpose this is not of significance.

Table III shows the total skin doses for the anteroposterior and lateral fields, including scatter from the right angle field. These data indicate that the scatter from the right angle field adds approximately 3–4 per cent to the skin dose.

B. *Cineroentgenography*. Skin dose measurements were made with a single plane cineroentgenographic unit utilizing a 5

TABLE III

TOTAL SKIN DOSE IN SERIAL ROENTGENOGRAPHY*

Exposure Time in Milliseconds	Exposure Rate in Films/Second	Anteroposterior Field			Lateral Field		
		Skin Dose in r	Scatter from Lateral Field in r	Total r	Skin Dose in r	Scatter from Anteroposterior Field in r	Total r
1	1.5	.96	.048	1.008	1.22	.041	1.261
1	6.0	.93	.040	.970	1.20	.040	1.240
2	1.5	1.97	.085	2.055	2.45	.087	2.537
2	6.0	1.90	.080	1.980	2.33	.083	2.413
4	1.5	3.40	.158	3.558	4.43	.148	4.578
4	6.0	3.20	.148	3.348	4.22	.140	4.360
5	1.5	4.05	.172	4.222	4.98	.180	5.160
5	6.0	3.84	.161	4.001	4.70	.168	4.868

* 30 film series.

inch Picker image intensifier energized by a 500 ma. Picker diagnostic unit, operating at maximum of 120 kv. Density of the film was controlled by an automatic brightness stabilizer, which affects the primary high tension voltage, to reduce the kilovoltage for thin parts and to increase it for greater thicknesses. During these tests the target table distance was 18 inches. The table top to fluoroscopic screen distance was 13.4 inches. The field size on the surface of the phantom was 2.4 by 2.4 inches. Filtration was 3 mm. of aluminum plus inherent filtration. No grid was used.

The dosimeter was placed between the phantom and the table top in the center of the field. During each test a 10 second exposure was made, since this was considered a representative total time for an average cineangiocardiographic series. Our system utilizes interrupter circuitry, providing a single radiation exposure of appropriate length with each frame. Table IV shows the operating factors at various camera speeds.

The effect of varying camera speed on dosage is shown in Table V. The dosage presented represents the average of 3 readings.

As anticipated, these data show the radiation dosage to be diminished with decreasing camera speed. While the relationship between dosage and camera speed is not strictly linear, discrepancies are explained by slight variations in film density which are evident in viewing the film strips.

Radiation incident to the preliminary fluoroscopic scanning for proper positioning of the field is not included in the data persented here.

TABLE IV

OPERATIONAL FACTORS FOR CINEROENTGENOGRAPHY AT VARYING FILM SPEEDS

Frames/Second	ma.	Exposure Time in Frame/Second
60	40	1/120
30	20	1/60
15	10	1/30
7.5	10	1/15

TABLE V

EFFECT OF VARYING FILM SPEED ON DOSAGE IN CINEROENTGENOGRAPHY*

Frames/Second	Average Dose in r
60	2.52
30	1.24
15	.80
7.5	.42

* 10 second series.

GONADAL DOSE

A. *Serial Roentgenography*. The dose to the gonadal area of the phantom was determined in a series of 30 films by placing the ionization chamber in the testicular location. To reproduce the position of the ovaries, a hole was drilled obliquely in the anterior abdomen to the approximate position of the ovary. The ionization chamber was placed in the depth of this cavity. Three measurements were made with the chamber in each of these positions. The average value for the testicular position was 1 mr and that for the ovary, 3 mr. In spite of the protected position of the ovary within the abdomen, its position closer to the irradiated area explains the higher dose rate. The accuracy of these small measurements is somewhat doubtful because of the known inaccuracy of the recording instrument at the low end of the scale.

B. *Cineroentgenography*. The gonadal dose during cineroentgenography was tested with the ionization chamber in positions identical to those described for serial roentgenography. Six 10 second series were made without detectable dose to the gonadal areas. A 30 second exposure yielded only 2 mr with the ionization chamber in the ovarian position.

DOSE TO ATTENDANT PERSONNEL

A. *Serial Roentgenography*. Using Schönander cameras, single and biplane examinations were performed with the phantom as previously described. Several series of 30 films were made at 1,000 ma., 100 kv. with 5 millisecond timing. Ionization chambers were placed in various locations about the phantom to simulate the positions of atten-

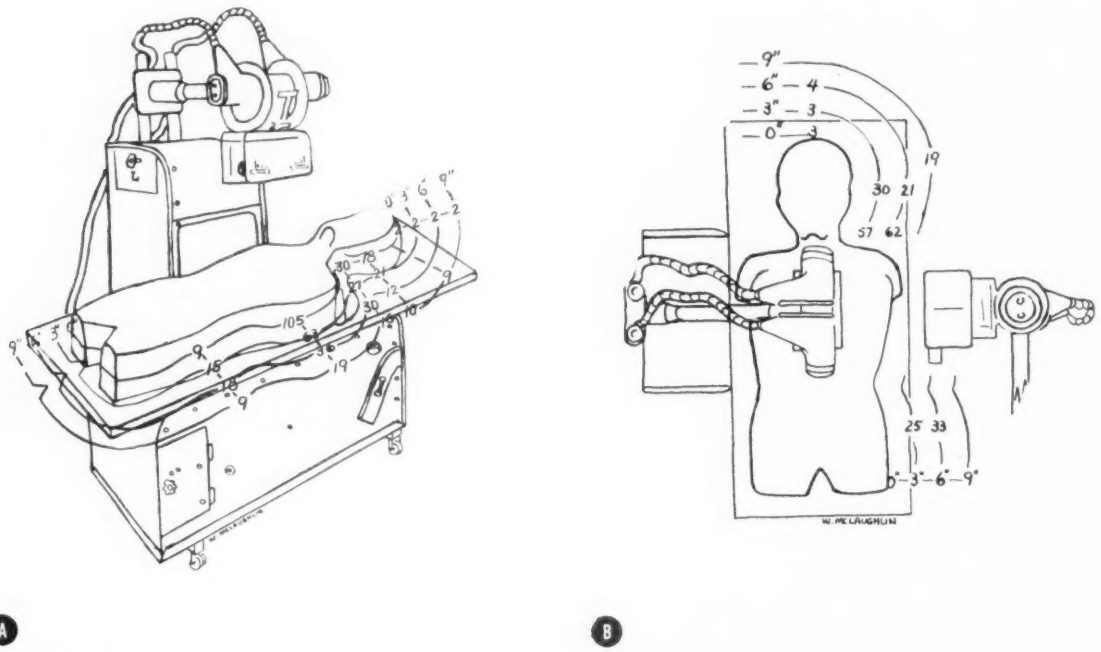

FIG. 1. Radiation doses in milliroentgens at table top level at various distances from the phantom. Distance between each line is 3 inches: (*A*) Single plane serial roentgenography; (*B*) biplane serial roentgenography.

dant personnel. Readings were taken at 0, 3, 9, and 12 inches from the phantom at table top level. Figure 1*A* illustrates the doses recorded with single plane anteroposterior examination. Figure 1*B* shows the doses in similar position with the biplane examination.

Of interest is the small magnitude of scattered radiation about the body of the phantom and the virtual absence of scatter about the head. The latter is due to the shielding effect of the head. The largest dose is encountered directly lateral to the area of the thorax being roentgenographed.

B. *Cineroentgenography*. With the ionization chamber in the same position in relation to the phantom as that described for serial roentgenography, tests for dose to attendant personnel were performed with the cineroentgenographic equipment. Ten second series at 60 frames per second were made. The only recordable reading obtained was 4 mr with the ionization chamber placed at a distance of 5 inches from the lateral aspect of the phantom, between the phantom and the lead apron which is suspended from the fluoroscopic screen. This measurement was recorded at table top level. No reading was obtained with the ionization chamber placed directly outside of the lead-rubber apron.

COMMENT

The ideal roentgenographic effect produced in this phantom was obtained in the serial roentgenographic experiments at 3 milliseconds. If one can then compare the doses obtained by this technique in the single anteroposterior plane with that obtained with 30 or 60 frames per second by cineroentgenography, one may compare the relative doses to the skin by the two methods. This is illustrated in Table VI. These data demonstrate that there is not a remarkable difference in dose to the exposed skin. However, it must be borne in mind that the area irradiated in the cineroentgenographic examination was much smaller than that with serial roentgenography. With the use of 8 or 11 inch amplifiers, the dose may well exceed that obtained in serial roentgenography by a significant degree.

It is apparent that with small field cine-

Table VI

COMPARISON OF SKIN DOSES WITH SERIAL AND CINEROENTGENOGRAPHY

Serial Roentgenography		Cineroentgenography 10 Second Series	
Number of Films	Skin Dose in r	Frames/ Second	Skin Dose in r
30	2.70	60	3.03
		30	1.67

roentgenography, scatter to the gonads is not a significant problem. In fact, even with the large fields of serial roentgenography the amounts which reach the gonads are very small. However, this situation may not apply to children, since the factors of distance and amount of intervening tissue are crucial in diminishing the dose to the gonads. In similar experiments ionization chambers were placed in the gonadal areas with shielding beneath the chamber to eliminate back scatter from the phantom. In these tests no readings were obtained, indicating that the scatter to the gonads is primarily through tissue rather than through air. For this reason, external shielding would probably add very little protection. However, proper collimation of the beam is of the utmost importance in protecting the gonads from direct and scattered irradiation.

With cineroentgenography the radiation hazard to attendant personnel is solved by the rubber apron attached to the fluoroscope. However, even in serial roentgenography the problem of scattered radiation is surprisingly small. The safest position for an attendant would appear to be at the head of the patient. A position lateral to the thorax should be avoided. In all instances, protection of personnel apparently can be easily handled by proper shielding with barricades. Here again, adequate collimation of the beam is of great importance in lessening irradiation to attendant personnel. Such collimation should include not only limitation of the field size to the necessary area of observation, but also the use of a collimator with sufficient lead in the diaphragm to prevent transmission of roentgen rays outside of the field of examination.

II. RELATIVE DIAGNOSTIC EFFECTIVENESS

The question of the relative diagnostic effectiveness of serial and cineangiocardiography is a matter of practical importance since the indication for each may differ depending upon the type of lesion which is suspected. In an attempt to shed some light upon this problem, experiments were performed to determine their relative merits. We wish to point out that the material presented here represents the results of a limited study and while certain conclusions suggest themselves, the problem requires considerable further investigation.

A fair comparison of the two methods requires that the anatomic structures to be demonstrated should be tested in the same subject by both techniques, under identical circumstances, and preferably at the same session. To this end angiocardiography was performed in dogs with both cine- and serial roentgenography.

The cineroentgenographic examinations were performed in single plane with a Picker 5 inch image amplifier, filming at either 30 or 60 frames per second with tri-x film (exposure characteristics: 120 kv., 40 ma. and 1/120 of a second for 60 frames per second, and 120 kv., 20 ma. and 1/60 of a second for 30 frames per second). The serial roentgenographic examinations were performed in single plane with a Schönander serialograph with dynapulse timing at 6 films per second (3 milliseconds, 100 kv., 1,000 ma.). Biplane examinations were abandoned early in the study because of difficulties in obtaining satisfactory anteroposterior projections in the dog.

Four anatomic entities were studied in dogs with both methods: the normal pulmonary and aortic valves, experimentally produced atrial septal defect, experimentally produced ventricular septal defect, and a coronary arteriogram. In each entity the

same animal was utilized for examination by both techniques. It soon became obvious that with the rapid heart action present in the dog, 30 frames per second was not the optimum speed for cineangiocardiography. Therefore, the remainder of the studies were made at 60 frames per second.

In reviewing the roentgenographic results, comparison was limited to the area of immediate interest since there was such a great difference in the total areas encompassed by the image amplifier and the Schönander cameras.

COMMENT

By comparing the examinations we feel that one can gain definite impressions of the relative merits of the two types of examinations. Unfortunately, the dynamics of cineangiocardiography cannot be presented in the printed page. The conclusions that are reached are probably what one might have expected; namely, that in those lesions where the dynamics of flow are important, or particularly, in the shunts, the cineangiocardiogram possesses real advantages. The movement of contrast material out of the normal confines of the chamber is very striking with the cineangiocardiogram and this movement immediately directs the attention of the examiner to the area of abnormality. On the other hand, detection of the shunt by serial roentgenographic examination is not as easily observed—but requires a more careful comparison of relative densities.

By contrast, in those entities where a study of detailed structure is important as, for example, where the details of valve leaflets or the coronary arteries are to be demonstrated, the serial roentgenographic examination appears to yield more information of value. With study of individual film or frames, the superiority of detail of the serialographic film is beyond question (Fig. 2, *A* and *B*).

These conclusions apply specifically to the equipment used in this study, and it is entirely possible that with further refinements in technique and equipment the relative merits of these techniques may be changed. We feel that further comparative testing is indicated, if possible in the human, with the ultimate goal of determining the ideal technique of examination for each of the congenital anomalies.

III. RELATIVE ROENTGEN OPACITIES OF CONTRAST MEDIA

Accumulated experience in angiocardiography suggests that there is a significant relationship between complications or

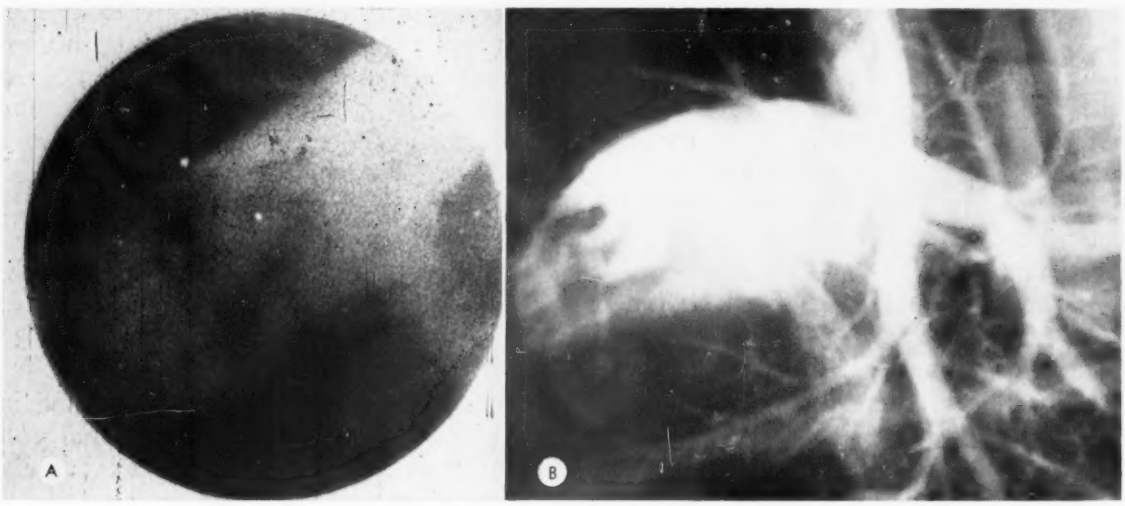

FIG. 2. Experimentally produced ventricular septal defect in dog: (*A*) Comparison of identical areas by cineangiocardiography; (*B*) serial angiocardiography.

death, and the volume and concentration of the contrast medium employed.[1–4] With the recent emphasis on media of increasing concentration (and viscosity), it appears desirable to determine if the increased concentration of the medium yields significant additional opacity to justify the concurrently increased toxicity. It occurred to us that the faster injection which is possible with a less viscous medium might perhaps compensate for its diminished opacity.

To test the validity of this concept, a set of chambers was constructed to compare the relative opacities of 50 per cent and 85 per cent hypaque in various dilutions with different kilovoltages (Fig. 3, *A* and *B*). The container was made of lucite with 8 channels of graduated depth from 10 mm. at the wide end of the channel to 1 mm. at the narrow end. Each medium was progressively diluted by 50 per cent three times. The container was roentgenographed at 80 kv. and 140 kv. through a pressdwood phantom of 10 cm. thickness. Adjustments were made in milliampere seconds to maintain approximately constant film density. Figure 3 demonstrates a surprising similarity between the 50 per cent medium and the 85 per cent medium and the various dilutions of each. This is further illustrated in Charts I and II where the relative densities of each chamber are plotted against densitometer readings. The convergence of the curves representing the densitometer readings from the narrow portions of chambers is probably due to the small amount of medium present. The superimposition of additional pressdwood at 10 cm. increments to a total of 30 cm. did not alter these relationships significantly.

Since the opacities of the 50 per cent and 85 per cent media were found to be similar

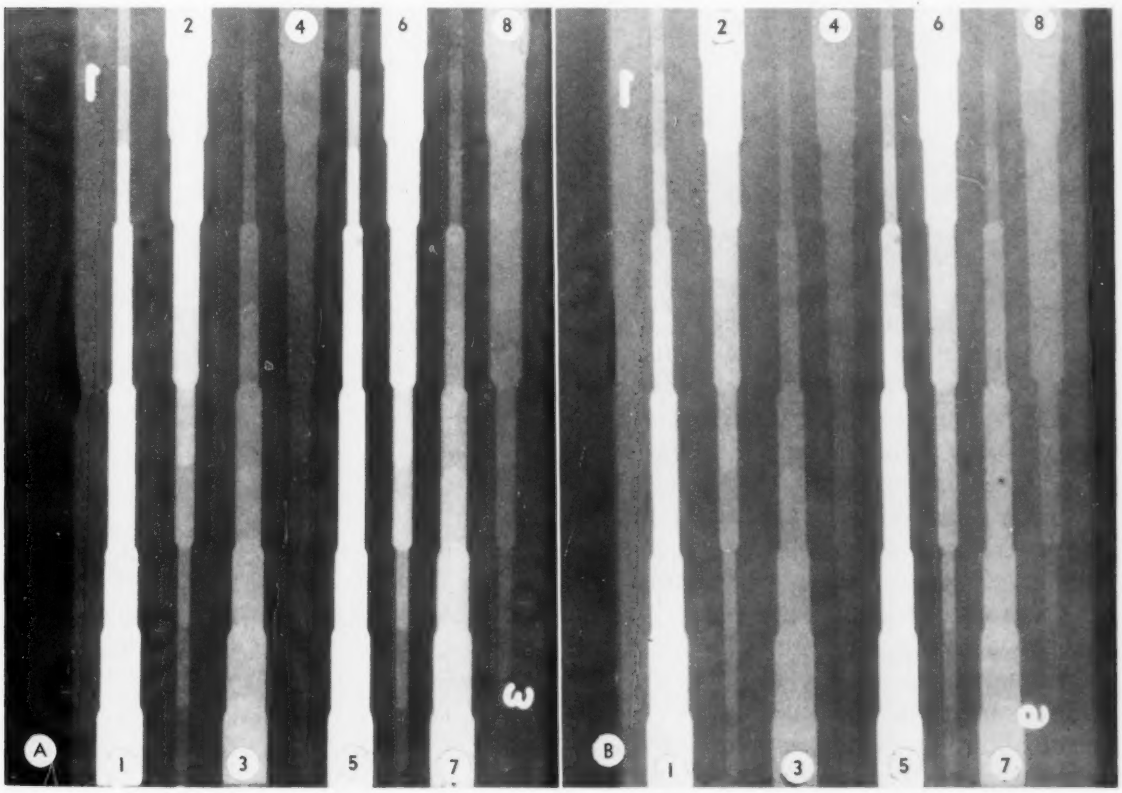

Fig. 3. Relative densities of media at different kilovoltage: (*A*) 80 kv. peak; (*B*) 140 kv. peak. The concentrations are indicated as follows: (1) 50 per cent, (2) 25 per cent, (3) 12.5 per cent, (4) 6.25 per cent, (5) 85 per cent, (6) 42.5 per cent, (7) 21 per cent, (8) 10.5 per cent.

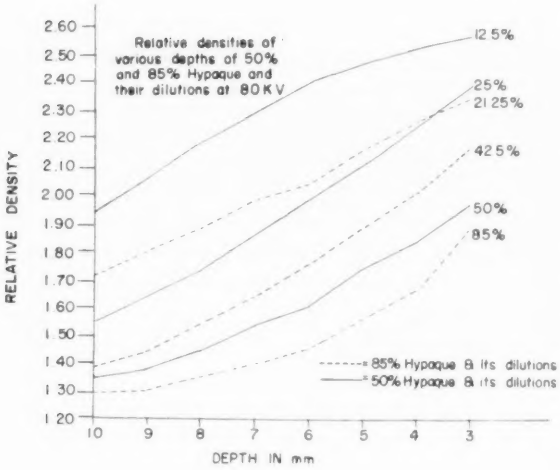

CHART I.

in a static situation, we then proceeded to attempt a similar comparison in a dynamic situation, to determine if the slight difference between their opacities might be compensated for by the faster injection rate possible with the 50 per cent medium.

An artificial heart was constructed from a plastic bottle with inlet and outlet hoses originating from the same end of the bottle. A constant flow of water was maintained through the hoses at a rate of 5 liters per minute. The bottle was radiographed through 10 cm. of pressedwood. Two injections were made through a No. 7 end opening catheter, of 125 cm. length. The catheter was placed in the afferent hose and two injections were made, one with 20 cc. of 50 per cent hypaque and the other with 20 cc. of 85 per cent hypaque. Each injection was accomplished by a Gidlund automatic injector operating at a pressure of 8 kg. per sq. cm. The injection time for the 50 per cent medium was 3 seconds, and for the 85 per cent medium 4 seconds. Exposures were made at 4 films per second for 3 seconds.

Comparison of films which were exposed at the same time intervals (in both series) showed consistently slower diffusion of the 85 per cent medium in the bottle, producing a more mottled opacification. Egress of the medium was also slower. Opacification, in spite of the slower injection, was greater with the 85 per cent medium, but this was not very striking (Fig. 4, *A* and *B*).

A similar series of experiments was performed in a dog. Four angiocardiographies were done in a 13 kg. dog with 50 per cent and 85 per cent hypaque in the order of 50 per cent, 85 per cent, 85 per cent and 50 per cent injections. Fifteen cubic centimeters of medium were used in each injection through the same catheter described above, the tip of which had been placed in the right ventricle. Again, the injection was made with the Gidlund automatic injector, operating at a pressure of 8 kg. per sq. cm. The injection of the 50 per cent medium was accomplished in two seconds and of the 85 per cent medium in three seconds. Exposures were made at 4 films per second for 3 seconds and then 2 films per second for 1 second. Exposure factors were 100 kv., 3 milliseconds, 1,000 ma. In this film series similar results were obtained. Again the chamber opacification with the 85 per cent medium was more mottled as opposed to the more homogeneous opacification with the 50 per cent medium. In the early angiocardiograms made before the termination of the injection of the 50 per cent medium, the difference in density of the two media is even less obvious than it was in the *in vitro* experiments (Fig. 5, *A* and *B*). The

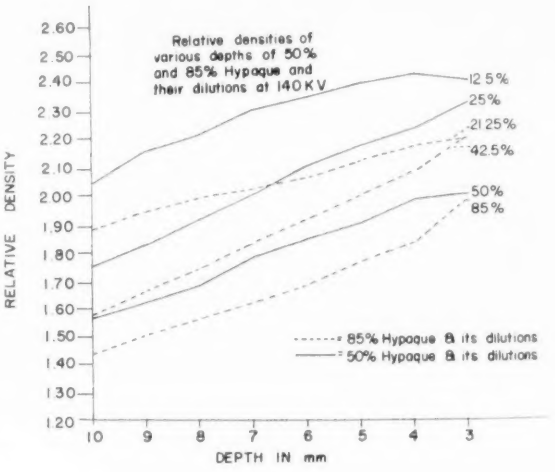

CHART II.

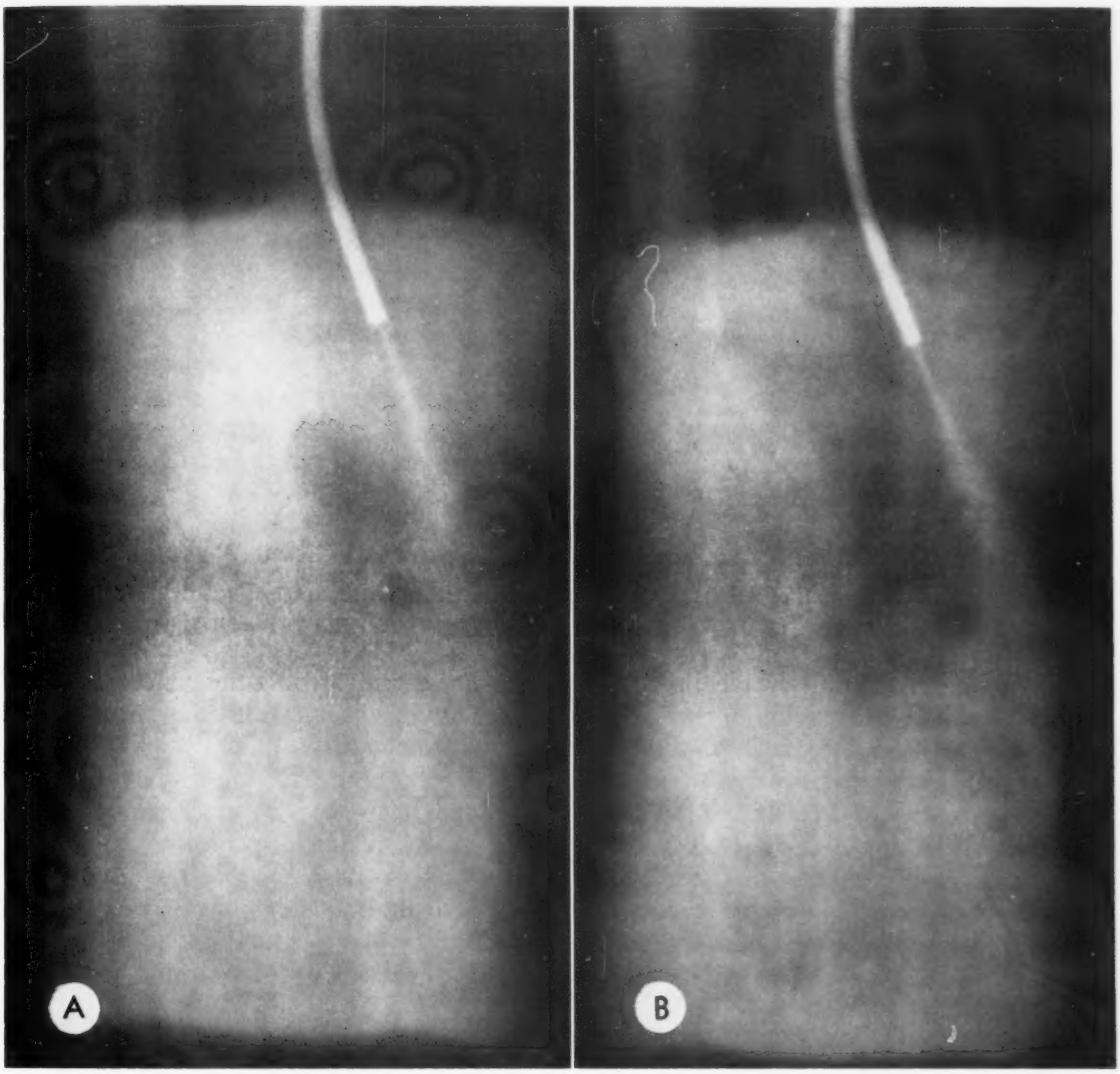

Fig. 4. Relative opacities of artificial heart by: (*A*) 50 per cent hypaque; (*B*) 85 per cent hypaque at same time interval after injection was started.

opacification of the right ventricle was considerably prolonged with the 85 per cent medium due to the longer injection time. The opacification of the chamber was achieved more rapidly with the 50 per cent medium and such opacification was similar in density to that which was obtained in later angiocardiograms with the 85 per cent medium (Fig. 6, *A* and *B*).

COMMENT

For optimum definition in angiocardiography, a large bolus of the medium should be delivered to the area to be visualized in a short period of time. It would appear that while media of greater concentration would be helpful in obtaining greater opacification, in practice, the difference between the opacity of the dilute and concentrated media is not as striking as one might anticipate from the difference in concentration. In addition, the advantage of the greater opacity of the more concentrated media is offset to a great extent by the longer injection time which results from the increased viscosity of the medium. A pro-

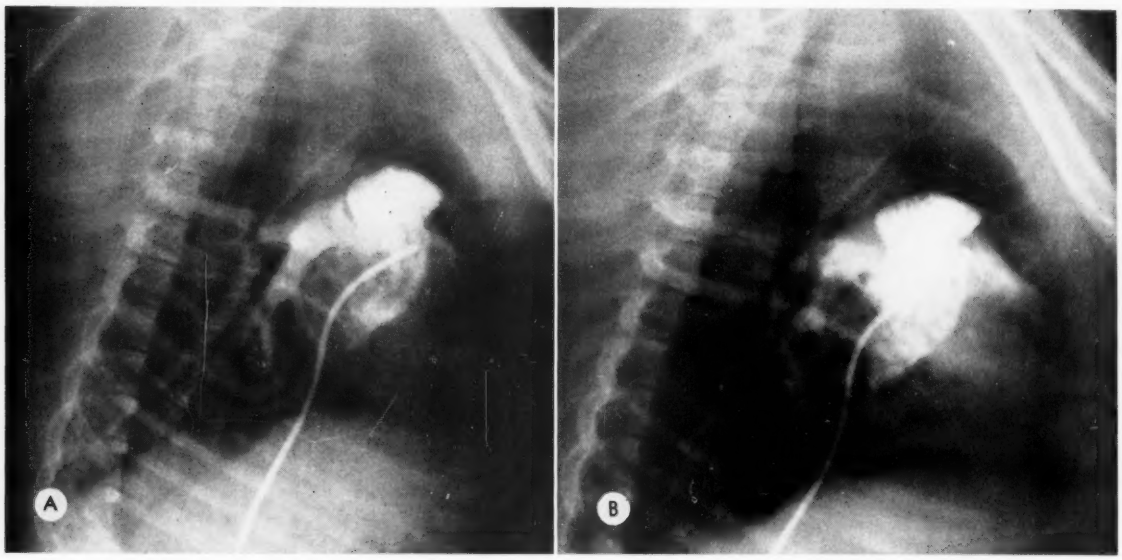

FIG. 5. Angiocardiogram of a dog one and three-fourths seconds after start of injection: (*A*) 50 per cent hypaque; (*B*) 85 per cent hypaque.

longed injection is undesirable in that it spreads the bolus of medium throughout the heart and pulmonary vasculature, while resulting in opacification of a given area which is very little different from that which could be obtained by a faster injection of a more dilute medium.

Increasing injection pressure to compensate for increased viscosity is not the final answer to this problem since increasing pressure carries with it the concomitant increased risk of trauma to the heart and of rupture of the catheter.

These experiments give real cause to reconsider the use of the higher concentration of contrast media for selective angiocardiography. It is probable that the use of more dilute media may not only be safer but as satisfactory roentgenographically. Clinical testing of this concept in patients will prob-

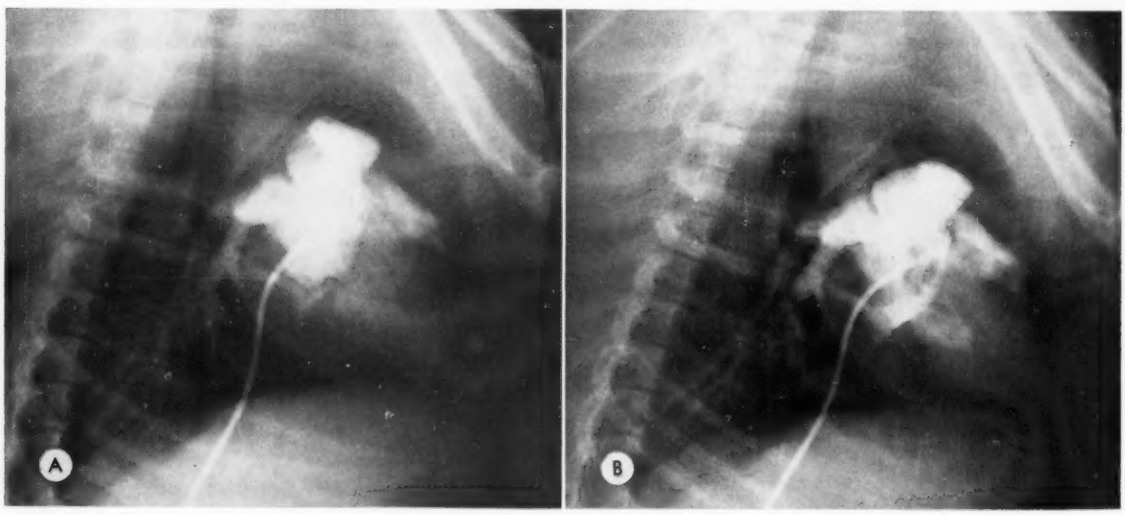

FIG. 6. Angiocardiogram of a dog: (*A*) 50 per cent hypaque one and one-half seconds after start of injection; (*B*) 85 per cent hypaque two and one-fourth seconds after start of injection.

ably provide the answer to the problem and will form the subject of a future report.

SUMMARY

1. There is little difference in the radiation dose to the skin with either cine- or serial angiocardiography, although more skin is, of course, irradiated with serial angiocardiography. With adequate collimation, gonadal dosage is so small that it is not considered a problem in adults. Simple protection measures will protect attendant personnel.

2. In those lesions where the dynamics of flow are important, cineangiocardiography possesses real diagnostic advantages. Detailed visualization of anatomic structures is the main advantage of serial techniques.

3. Experimental testing indicates that the radiopacity of 50 per cent and 85 per cent hypaque is strikingly similar and that the advantages of the additional opacity of the more concentrated medium are offset to a great extent by the disadvantages of its inherent increased viscosity and toxicity.

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THE EFFECT OF CARDIAC IRRADIATION UPON THE ELECTROCARDIOGRAM OF THE NORMAL CANINE HEART*

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THE reports in the literature are conflicting regarding the effects of radiation upon the heart.[1,2] Disturbances of cardiac rhythm including heart block, auricular fibrillation, auricular flutter and paroxysmal tachycardia have been noted.[2] Prolongation of the PR interval, diminished QRS voltage, and T wave changes[5,7,8] have been reported. Others,[3,4,13] however, have found no significant electrocardiographic changes following irradiation of the thorax. In the above studies, the duration and dosage of radiation administered were variable and may account for the conflicting results. Further conflict may be due to the fact that these studies were carried out in different animal species and in humans with varying underlying diseases.

In this laboratory, we have been interested in the possible value of cardiac irradiation as a therapeutic measure in coronary artery disease by inducing an increase in myocardial vascularity.[11] The purpose of this study is to report the effects on the electrocardiogram of irradiation of the normal canine heart under controlled conditions of dosage and time. It is believed that this information is of value because of the contemplated use of these same dosages in the therapy of coronary artery disease.

METHODS

Pre- and postradiation electrocardiograms were taken in a series of 52 healthy mongrel dogs (Table 1). Each dog had a scout roentgenogram of the chest made to determine the heart location and size. This area was mapped on the dog's thorax on both the left and the right sides. The heart was then irradiated by means of three treatments to the left chest area, and two to the right chest area during a 14–17 day period. The treatments were given with a parallel opposing pair of fields ranging in size from 80–120 cm.^{2}. The average separation of the fields was 10 cm. Two hundred kilovolt roentgen rays, which after filtration had a half value layer of 0.9 mm. of copper, were utilized at a focal skin distance of 50 cm.

The calculated total dose to the heart in one group was 1,300 r; another group received 2,000 r; and a third group 2,500 r.

TABLE I

NUMBER OF EXPERIMENTAL ANIMALS, RADIATION DOSAGE AND FOLLOW-UP PERIOD

Group	No. of Dogs	Estimated Dosage to the Myocardium (r)	Electrocardiographic Follow-up (da.)
Control	5	0	7
Short Term	15	1,300	5–7
	20	2,000	5–7
	4	2,500	5–7
Total	39		
Long Term	3	1,300	30
	2	2,000	30
	1	1,300	60
	1	2,000	60
	5	1,300	90
	1	2,000	90
Total	13		

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This latter group was irradiated in a manner similar to the other groups with the exception that three treatments were given to each chest area and the source of irradiation consisted of a cobalt 60 teletherapy unit.

Prior to the recording of the electrocardiograms, the dogs were anesthetized with sodium nembutal (25–30 mg. per kg. of body weight) to insure immobility and to allow for uniform positioning of the animals. The animals were placed on their right sides with the left chest up. Skin contact electrodes were used on all four extremities.

Electrocardiograms were taken prior to irradiation and at varying intervals following the last dose of radiation (Table I). The dogs which were studied 5–7 days following the last radiation treatment will be referred to as "short term." The dogs studied at 30, 60, or 90 days following the termination of irradiation will be referred to as "long term." Electrocardiograms were also taken on nonirradiated dogs on two separate occasions to determine the variations arising from repeat electrocardiography alone.

An analysis of rhythm and rate was performed on the material obtained and subjected to statistical evaluation. ST segment changes were similarly studied. Observations were made as regards PR interval, QRS duration, and T wave configuration in bipolar extremity leads. Unipolar extremity leads were used for confirmation.

RESULTS

Rhythm. In none of the dogs, either before or after irradiation, was any ectopic cardiac arrhythmia noted. Sinus arrhythmia was noted in 5 dogs before irradiation and in 10 dogs after irradiation (Table II). Two of these dogs had sinus arrhythmia both before and after irradiation. Similar variability on repeated electrocardiograms was noted in the control dogs. The different frequency of sinus arrhythmia before and after irradiation is not significant ($P > .10$) and was unrelated to dosage or length of follow-up.

TABLE II

FREQUENCY OF SINUS ARRHYTHMIA

Group	No. of Dogs	Sinus Arrhythmia	
		Preradiation	Postradiation*
Control	5	1	2
Short Term	39	3	4
Long Term	13	2	6
All 1,300 r	24	1	5
All 1,300 r	28	4	5
All Irradiated	52	5	10†

* Repeat electrocardiograms in case of control dogs.
† Chi-square equals 1.946 ($P > .10$).

Rate. There was a mean increase in the ventricular rate following irradiation in the short term dogs at each radiation dose level (Table III). This increase was highly significant for the total short term group ($P < 1$ per cent). There was no significant difference in the postradiation mean ventricular rate between the dogs receiving 1,300 r and those receiving 2,000 r.

When the electrocardiogram was repeated 30 to 90 days following the completion of the course of irradiation (long term dogs), the mean ventricular rate was less than the mean ventricular rate before irradiation. There was marked individual variability and this difference was not significant.

Intervals. There was no significant difference in the QRS duration or PR interval before or after irradiation. The QT segment was not measured because of marked variability depending on the configuration of the T waves.

ST Segment. The ST segments were considered depressed if they were 0.5 mm. or more below the baseline considered as the TP or PR segment. The range of depression was 0.5 to 1.5 mm. and the range was similar in the dogs before and after irradiation. There were ST segment depressions in leads II and III in 71 per cent of all dogs before irradiation (Table IV). The percentage of

TABLE III

EFFECT OF RADIATION ON VENTRICULAR RATE

Group	No. of Dogs*	Average Ventricular Rate		t†	Level of Significance‡
		Preradiation	Postradiation		
1,300 r, Short Term	14	148	164	1.82	>5%
2,000 r, Short Term	15	149	176	2.32	<5%
2,500 r, Short Term	3	138	167	2.44	>5%
All Dogs, Short Term	32	147	170	3.39	<1%
All Dogs, Long Term	7	183	172	0.78	>5%
ALL SHORT TERM DOGS					
1,300 r	14		164		
2,000 r	15		176	0.96§	>5%

* Includes only dogs with regular sinus rhythm before and after irradiation. Dogs with sinus arrhythmia either before or after irradiation have been excluded from these calculations.

† The t test of significance used to test a null hypothesis

$$t = \frac{M_o - M_h}{\sqrt{\frac{\Sigma d^2}{N(N-1)}}}$$

M_o = observed mean difference.
M_h = hypothetical mean difference (zero).
N = number of pairs.
d = difference between pairs minus the observed mean difference.

‡ The frequency with which the differences observed could be based on chance. A level of significance of 5 per cent or less is considered to indicate a significant difference.

§ The t test of significance is applied here to the differences in postradiation rate between the 1,300 r and 2,000 r short term dogs. The formula for this calculation is from Edwards.[1]

dogs with ST segment depressions in the bipolar extremity leads was almost identical ($P > .95$) in all groups prior to irradiation. Following irradiation, only 33 per cent of the dogs had ST segment depressions in leads II and III. This change was highly significant ($P < .01$). This trend was noted in each group regardless of the size of the dose or length of follow-up. ST segment depressions in leads II and III were less frequent following irradiation in the long term dogs than in the short term dogs ($P < .10$) and were less frequent in the dogs receiving 1,300 r than in the dogs receiving more than 1,300 r ($P < .10$). There was significant variability in the postradiation frequency of ST segment depressions in leads II and III between the four groups as defined in Table IV ($P < .05$). It was also noted that some variability was present in the control dogs which did not receive irradiation.

In none of the dogs, control or experimental, were ST segment elevations greater than 0.5 mm. noted in the bipolar extremity leads before irradiation. In 3 dogs, ST segment elevations were noted in lead II following irradiation. Two of these also had ST segment elevations in lead III. As seen in Table IV, the occurrence of these elevations was unrelated to radiation dosage or length or follow-up.

T Waves. There is a marked variability in the T wave pattern of the dog as recorded in the unipolar and bipolar extremity leads. In addition to the variability between dogs, repeated electrocardiograms on the same dog show variation without any apparent cause. There were gross changes observed in the repeat tracings of 4 of the 5 control dogs in our series. Following irradiation, 52 per cent of the experimental dogs had gross T wave changes in the bipolar extremity leads. There were no T wave patterns observed after irradiation which were not also seen in one or more animals prior to irradiation. A cove-plane configuration was never observed. There were no T wave patterns which were significantly more frequent after irradiation

than before irradiation and there was no consistency of change.

DISCUSSION

It is apparent from the results obtained that at the dosage levels employed in this study there is no marked interference with normal A-V conduction. The transient increase in mean ventricular rate noted one week following the completion of the course of irradiation may be related to a temporary inhibitory effect upon the vagus. Ellinger[2] has reported on studies by French workers,[14,15] in which irradiation of the exposed vagus in rabbits with 1,500 r resulted in a decrease in the response to electrical stimulation. Langer,[6] following experiments upon cats, stated that "roentgen rays given in certain amounts influence the sympathetic or parasympathetic nerves and a certain paralyzing effect takes place." The possibility of direct myocardial damage as an etiologic factor in the increase in ventricular rate must also be considered. However, pathologic examination of hearts receiving the same dosages utilized in this study did not reveal any evidence of myocardial damage.[10] The increase in rate appears to be a transient phenomenon and is not present 30–90 days later.

Intravenous anesthesia with barbiturates in animals may produce depressions of ST segments in lead III.[9] In our series, sodium nembutal was used and probably accounts for the great frequency of ST segment depression observed in leads II and III prior to irradiation. Of great interest is the significant decrease in the frequency of ST segment depression in these same leads following irradiation. It is difficult to attribute this difference to a barbiturate effect, as the dosage of nembutal administered in any single dog did not vary significantly. Anoxia, as a differential factor, may be ruled out by the fact that assisted respiration was not utilized while the electrocardiograms were being recorded either before or after irradiation. Perhaps the change in frequency of ST segment depression noted can be explained on the basis of an acquired tolerance to barbiturate which resulted from the repeated use of nembutal. A hypothesis, for which we have no further evidence, is that the radiation of itself caused the decreased frequency of ST segment depressions; the significance of this is not known.

ST segment elevations in lead II were

TABLE IV

ST SEGMENT BEFORE AND AFTER IRRADIATION

Group	ST Segment Depressed in Leads II and III				ST Segment Isoelectric in Leads I, II and III				ST Segment Elevated in Lead II				P*
	Preradiation		Postradiation		Preradiation		Postradiation		Preradiation		Postradiation		
	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent	
Short Term	28	72	16	41	11	28	21	54	0	0	2	5	<.02
Long Term	9	69	1	8	4	31	11	85	0	0	1	8	<.01
1,300 r	18	75	5	21	6	25	18	75	0	0	1	4	<.01
1,300 r	19	68	12	43	9	32	14	50	0	0	2	7	>.10
All Irradiated	37	71	17	33	15	29	32	62	0	0	3	6	<.01
Control	2	40	1	20	3	60	4	80	0	0	0	0	—

* The value of P is obtained from a computation of chi-square. As applied in this table, it is an index of the significance of the difference in frequency of occurrence of ST segment depressions in the dogs before and after irradiation. A P less than .05 indicates a difference which is probably not due to chance alone.

$$\text{chi-square} = \frac{\Sigma(o - e)^2}{e}$$

o = the observed frequency.
e = The corresponding expected frequency (pre- and postradiation frequencies were assumed to be equal).

noted in 3 animals postradiation. This was not seen in any animal preradiation. This would suggest epicardial, or pericardial involvement although we cannot explain the sporadic occurrence unrelated to time or dosage.

The spontaneous variation of the T waves in the same dog at different times and the numerous "normal" patterns have been noted.[9] This is in accord with our experience. Although we never observed a cove-plane configuration and were unable to establish a consistent pattern of change following irradiation, significant changes in a single dog may readily escape detection. Therefore, no satisfactory conclusion can be made regarding the effects of irradiation on the T waves of the electrocardiogram in our series.

SUMMARY AND CONCLUSIONS

1. Electrocardiograms were obtained on 52 normal dogs before and after cardiac irradiation with 1,300 r; 2,000 r; and 2,500 r.

2. No ectopic cardiac arrhythmias were noted on electrocardiograms obtained 7–90 days following the completion of the course of irradiation.

3. A mean increase in the ventricular rate was noted 7 days following the completion of the course of irradiation, but was not present 30–60 days later.

4. There was no prolongation of PR interval or QRS duration following cardiac irradiation.

5. At the dosage levels employed, irradiation of the normal canine heart produced no electrocardiographic changes indicative of gross myocardial damage. This was noted to be true as long as 90 days following the completion of the course of irradiation.

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FIVE YEAR CURE IN A CASE OF MALIGNANT HEMANGIOENDOTHELIOMA OF BONE TREATED WITH ROENTGEN RAYS*

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MALIGNANT hemangioendothelioma of bone is a rare neoplasm,[3,7,8] which, apparently, does not develop through malignant changes in a previously benign hemangioma of bone. Thomas[8] collected 15 cases of this aggressive and metastasizing vascular tumor and classified them into two groups: one in which the endothelial proliferation predominates; the other in which the outstanding feature is represented by the pronounced vasoformative tendency. Stout's classification[7] postulates their origin from the adventitial, medial, or intimal layers of the vessel wall, respectively, thus listing: hemangio-pericytoma (including the malignant variety of glomus tumor), leiomyosarcoma of vascular origin and hemangioendothelioma.

Because of the limited experience of any one individual with this type of tumor, it was thought worthwhile to report this case in which there has been a five year cure with roentgen therapy.

REPORT OF A CASE

The patient, a thirty year old white male, had had a left hemithyroidectomy and a left radical neck dissection at the age of twenty-four (1952), because of papillary adenocarcinoma of the thyroid gland, which had already metastasized to the left jugular lymph nodes.

In September, 1953 he developed dull pain in the left shoulder area and a roentgenogram showed rarefying lesions in the proximal and distal ends of the left clavicle and in the acromion and spine of the left scapula (Fig. 2). The lesions were described as being expansile and loculated in character. Survey of the rest of the skeleton was negative. In addition to the bone lesions, he was also found to have a small, subcutaneous nodule in the left supraclavicular area. Clinically, the patient was thought to have metastases from the thyroid carcinoma. Biopsy of the left clavicle was performed and the nodule in the supraclavicular fossa was also removed. In both instances, a diffuse vascular tumor was found (Fig. 1). It consisted of multiple, freely anastomosing channels, lined by endothelial cells; the later were rather prominent and occasionally were bizarre in shape and showed mitotic activity. Silver stains clearly defined the relation of the atypical endothelium to the vascular sheaths. No tumor emboli were noted and the bone trabeculae were thin, but not otherwise remarkable.

The microscopic diagnosis was hemangioendothelioma (Thomas' angiosarcoma) of the left clavicle, metastasizing to the subcutaneous tissue of the left supraclavicular fossa.

Because surgery would have involved loss of the left upper extremity in the course of resection of the entire left shoulder, it was decided to give the patient a therapeutic trial of rapid, intensive, roentgen-ray treatment and then consider future procedure. He was, therefore given 2,500 r to the left anterior acromioclavicular region and 2,500 r to the left posterior scapular region over a period of four weeks (250 kv. through a 0.5 mm. copper filter).

Radiation therapy was followed by prompt disappearance of the local pain and tenderness in the left shoulder. No further progression of the lesions was noted and within two months there appeared to be minimal contraction of the lesions, manifested by better bone definition.

In view of the encouraging clinical and slight roentgenographic improvement, it was decided to withhold radical amputation and to continue checking the patient periodically. This has been done for the past five years. The roentgenographic findings are summarized as follows: On September 14, 1953 (before treatment) the distal end of the left clavicle was ballooned-out to a 2×3 cm. rarefied, loculated

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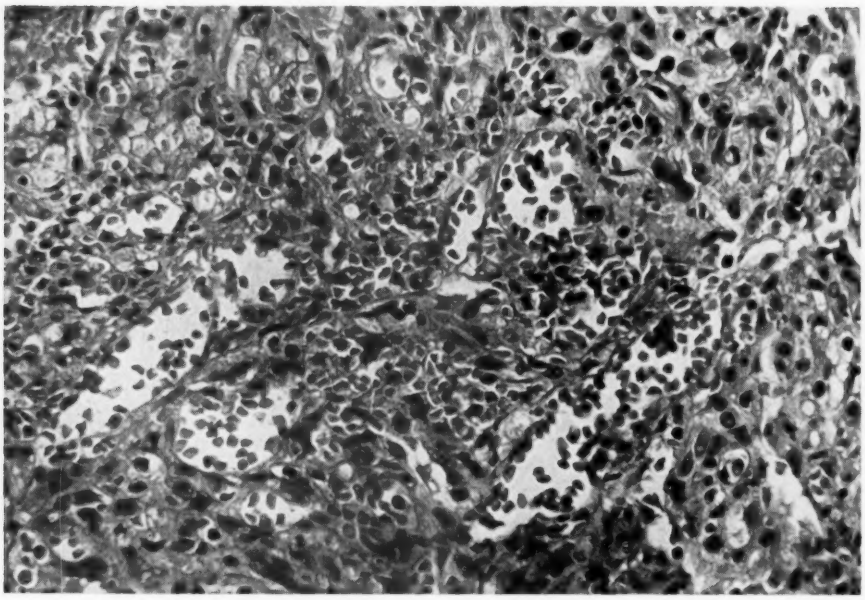

FIG. 1. Biopsy of the left clavicle. Vascular slits lined by rounded or heaped-up endothelium; also, solid masses of tumor cells compressing the neoplastic blood vessels (×110).

lesion. The outline of the lesion was very thin, but not interrupted. In the adjacent portion of the acromion, a similar lesion was seen (Fig. 2). On October 24, 1958 the distal end of the left clavicle was no longer expanded. It now measured 1.5×2 cm. The rarefied nature of the lesion was less pronounced because of partial filling in. The walls of the lesion and of the individual locules were better defined and broader. The acromion lesion showed changes of the same character (Fig. 3).

FIG. 2. Roentgenogram taken on September 14, 1953 shows loculated, rarefying lesions of the left clavicle and acromion.

The patient has been working full time as an eighth grade teacher and in November, 1959 was found to be in good health with no change in the roentgenographic findings.

DISCUSSION

The diagnosis of hemangioendothelioma of bone can be suspected roentgenographically but can be made definitely only by histologic study. Metastatic carcinoma from the thyroid, kidneys or lung must be considered foremost in the differential diagnosis. Other lesions which may be a source of confusion are: (a) benign cyst of bone, (b) multiple myeloma, (c) hemangioma, (d) giant cell tumor, (e) osteosarcoma, (f) chondrosarcoma, and (g) xanthomatosis of bone.

Standard texts on bone tumors, such as those of Coley,[1] and Geschickter and Copeland,[2] favor radical surgery for treatment of malignant hemangioendothelioma. Coley

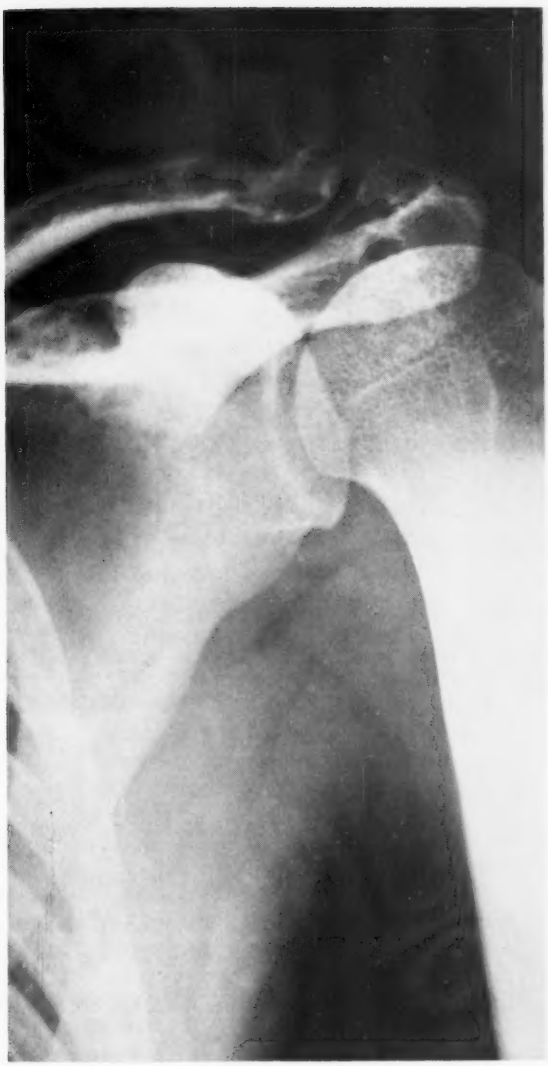

Fig. 3. Roentgenogram on October 24, 1954, one year after treatment, reveals partial filling-in of the lesion with better bone definition.

advises "early removal of the tumor bearing portion of the bone since these tumors are less radiosensitive than Ewing's sarcoma of the bone."

On the other hand Leucutia,[5] while agreeing that surgery is the preferred treatment, states that "roentgen therapy is also useful. The radiosensitivity of angioendothelioma of bone conforms to that observed in angioendotheliomas generally and is only slightly less pronounced than that seen in Ewing's sarcoma."

Lichtenstein[6] cautions that hemangioendotheliomas "are likely to be so aggressive or so far advanced by the time they are recognized as to have a serious prognosis despite radical surgery."

Fig. 4. Roentgenogram in October, 1958, discloses no significant change since 1954.

Hauser and Constant[4] reported a case of hemangioendothelioma in each hip gradually enlarging and filling a large part of the pelvis. The patient was alive nine years later. The lesion continued to grow in spite of deep roentgen therapy. These authors concluded: "The literature shows that this type of therapy does not resolve the lesion."

Portmann's text, "Clinical Therapeutic Radiology," contains reproductions of skull roentgenograms showing angioendothelioma of bone before and fourteen years after biopsy and supervoltage roentgen therapy. The osteolytic lesion is completely filled in by dense new bone but no clinical details are given.

Thomas,[8] who in 1942 reviewed 15 cases of malignant hemangioma of bone, stated that they were only moderately radiosensitive and early diagnosis and radical surgical treatment are essential for cure. Am-

putation had been performed in 9 cases with apparent cure in 4. One patient was alive ten years after surgery. Ten patients were treated by irradiation with death occurring in 6. In the 4 surviving patients treated by irradiation, amputation was done in all. In one case, an apparent cure was brought about in the primary lesion, but the tumor recurred in an adjoining bone five years later and amputation was necessary.

It is important to note that in the case cited above by Thomas, curettement combined with heavy irradiation was followed by complete healing of the tumor which involved the calcaneus. A roentgenogram made three years after treatment showed complete filling in of the cavity in the bone and pathologic examination of the foot following later amputation revealed the calcaneus to be small and atrophic but with no evidence of tumor tissue. The development of an angiomatous tumor in the adjacent tarsal bones several years later cannot be regarded as proof of the futility of roentgen therapy, but rather as evidence of the multicentric origin of these tumors.

It is important to emphasize that from the histologic examination alone it is not possible to predict whether these lesions will behave merely as a local malignancy or whether they will metastasize. This difficulty in prognosis obviously has a significant bearing on the treatment of the case.

In conclusion, it may be said that the literature in this rare type of blood vessel tumor favors surgery as the preferred type of treatment. However, where the lesion is so situated as to involve mutilating surgery, it may be worthwile to try intensive radiation therapy first.

SUMMARY

1. A case is reported of a patient in whom radiation therapy has apparently achieved a five year cure of a malignant hemangioendothelioma of the left shoulder.

2. Although the consensus of opinion among authorities on this rare tumor favors radical surgery as the treatment of choice, there may be indication for trial of radiation therapy when surgery would involve a mutilating procedure.

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FACTORS INFLUENCING RESPONSE AND RECOVERY OF GRAFTED SKIN TO IONIZING IRRADIATION*

EXPERIMENTAL OBSERVATIONS

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THE altered tolerance of irradiated grafted skin is a complex problem. Since tolerance is measured by both response and recovery, it is important to present both aspects as fully as possible. The degree of graft vascularity is a central consideration, but other factors play an important role in the end effect. The limitations of studying and analyzing many variables on patients are obvious and these led to the undertaking of an experimental program. The results of the program give us further insight and serve as a guide for clinical therapeutics.

METHOD OF STUDY

The best animal for studying skin responses to irradiation is the pig. In both its macroscopic and microscopic appearance, its epidermis and dermis closely resemble those of the human. The continual increase in size of these animals makes housing a problem and limits the number of animals in this program. However, this is offset by providing skin grafts of reasonable size to study and allowing for the use of similar physical treatment factors as in humans.

Autografts measuring 5×5 cm., of both split and full thickness, were made on Chester White and Yorkshire pigs weighing 10 to 12 kg. Split thickness grafts were prepared with a Brown electric dermatome set at .030 inch. Full thickness grafts were made by free dissection. In pig Experiments I, II, III and IV, a period of three to six weeks was allowed for the grafts to firmly "take" and irradiation was begun thereafter. In Experiment V, irradiation was begun on the day after grafting.

Two-thirds of a graft and adjacent normal skin were included in each port irradiated. The remaining one-third of each graft with adjacent nonirradiated normal skin was ultized as a control. Biopsy specimens were obtained at periodic intervals during irradiation of the various grafts. Photographs were made sequentially, but in biopsying a site, it was necessary to sacrifice the photographic sequence. Interpretative graphs are drawn from weekly observations of both grafted and normal skin sites, irradiated and nonirradiated.

EXPERIMENT I: TO DETERMINE THE TYPE OF RADIATION REACTION IN SPLIT AND FULL THICKNESS GRAFTS (Fig. 1 and 2, *a–f*)

TECHNIQUE

Four split and four full thickness grafts were irradiated with 112 kv. radiation utilizing a 5.5 cm. (diameter) round port, focal skin distance 20 cm., half value layer 3.7 mm. Al. Successive skin doses, with backscatter, of 1,000 r; 1,000 r; 2,000 r; and 2,000 r were given at nine day intervals, providing a total skin dose of 6,000 r in four weeks to each port.

RESULTS

The sequence of events is shown graph-

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The contents of this article are the personal views of the Air Force author and are not to be construed as statement of official Air Force Policy.

Experiments were conducted according to the "Rules Regarding Animal Care" as established by the American Medical Association.

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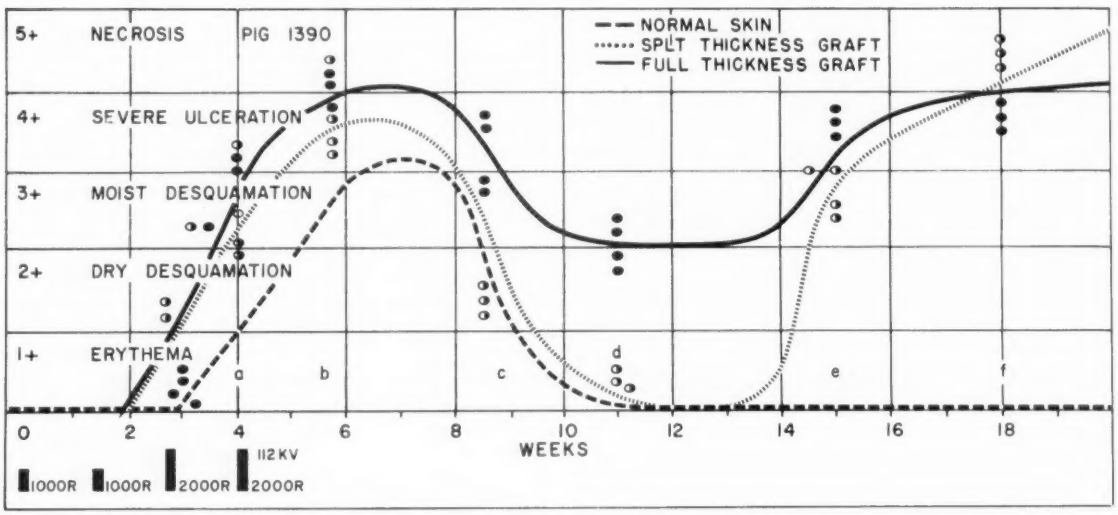

FIG. 1. Experiment 1. Type of radiation reaction in split and full thickness grafts. Grafted sites reacted earlier and more briskly than normal skin. Recovery was delayed in all the grafts and at three months the graft sites underwent necrosis whereas normal skin remained healed.

ically and pictorially. The following is a brief description of the reaction:

1. *Grafted Sites:* At the end of the second week of irradiation, an erythema was recognized on the grafted sites. This appeared earlier and progressed more rapidly than on normal skin. Moist desquamation occurred on the fourth week (Fig. 2*a*) and became quite severe on the fifth week (Fig. 2*b*). Evidence of recovery began at nine weeks (Fig. 2*c*) and the greatest degree of healing was seen at the twelfth week (Fig. 2*d*) when most of the areas re-epithelized quite rapidly. At three months, however, quite unexpectedly the grafted sites reversed their course and underwent severe,

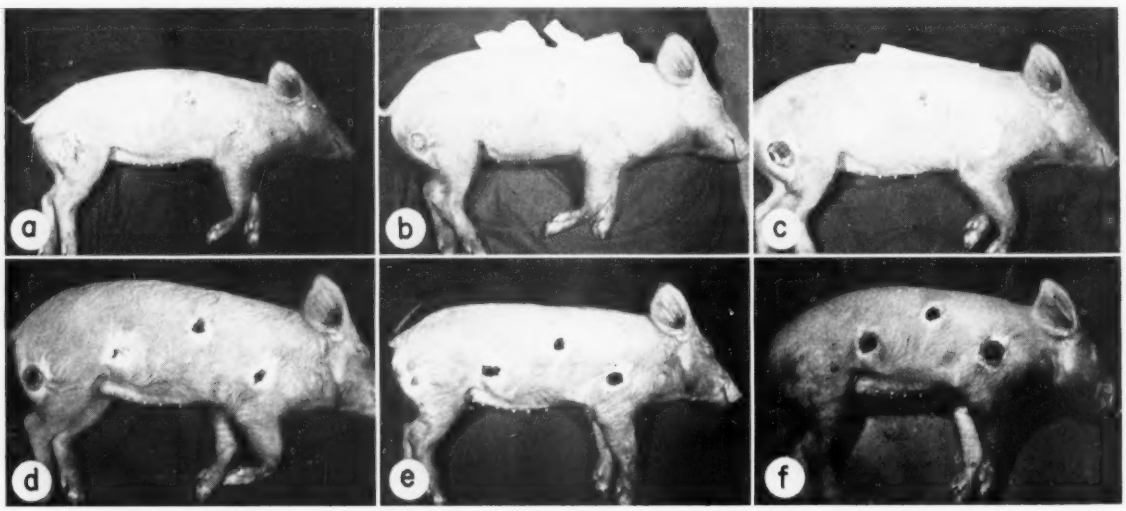

FIG. 2. Experiment 1, Pig 1490. (*a*) Moist desquamation of grafts is shown. (*b*) Grafted sites have reacted with severe ulceration; normal skin generally shows moist desquamation. (*c*) Healing phase of graft and normal skin reactions is shown. One split thickness graft on the right hind quarter underwent early necrosis. (*d*) Peak of recovery phase is shown; graft over abdomen has superficial crusting removed. (*e*) Early phase of graft necrosis is presented; necrotic defect on the right hind quarter is being healed. (*f*) Late necrosis of grafts.

deep necrosis (Fig. 2, *e* and *f*). This was the status at the time the animal was sacrificed as its size was too large to handle in our animal quarters.

One split thickness graft on the right hind quarter developed a deep crater with necrosis at the fourth week, this being earlier than the other seven grafts which underwent only late necrosis.

2. *Normal Skin:* Normal skin began to react after the grafted sites in all instances. The earliest signs of erythema appeared in the third week after 4,000 r had been delivered in three weeks. This reached a moist desquamation at the sixth week. The epithelitis plateaued for two more weeks, began to decline on the eighth week, and was completely healed by the eleventh week.

In summary, freshly grafted sites (less than three months old) reacted earlier and more briskly than normal skin. Recovery was delayed in all the grafts and at three months the sites underwent necrosis whereas normal skin remained healed. In general, split thickness grafts were less reactive and recovered more quickly than full thickness grafts. For any specific graft, this is less predictable as there is a range of overlap. This is evidenced by one of the split thickness grafts which underwent early necrosis.

EXPERIMENT II: TO STUDY THE EFFECT OF ORTHOVOLTAGE IRRADIATION ON GRAFTS (Fig. 3*a* and 4*a*)

TECHNIQUE

Four split and four full thickness grafts were irradiated with 280 kv. radiation utilizing a 5 cm. square port, focal skin distance 50 cm. An initial surface dose, with backscatter, of 2,000 r was administered and 1,000 r at weekly intervals giving a total surface dose of 6,000 r to each port in four weeks.

RESULTS

1. *Grafted Sites:* After the beginning of irradiation, no graft response was noted for two weeks. After two weeks, however, early changes appeared and continued to progress until the fourth week. Typically, a small area of denudation began along a graft margin, spread centrally in the graft, and extended along the graft margin. On the portion of the graft included in the treatment field which did not react with moist desquamation, erythema could usually be observed. One split thickness and two full thickness grafts developed confluent crusting on all of the graft irradiated, but this was rather superficial. Full thickness grafts, in general, reacted more

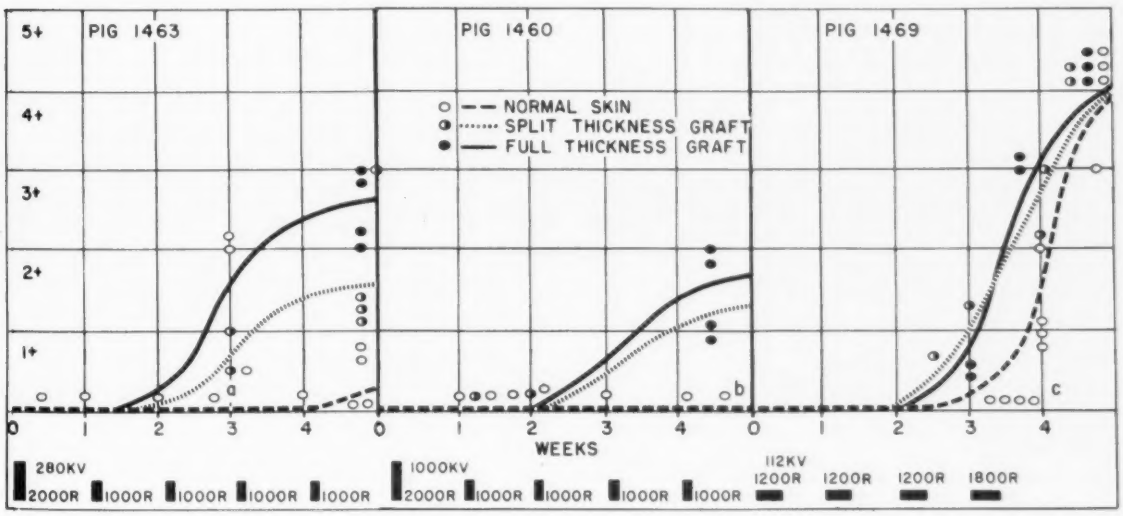

FIG. 3. (*a*, *b*, and *c*) Experiments II, Pig 1463, (280 kv.); III, Pig 1460 (1,000 kv.); and IV, Pig 1469 (112 kv.). The severity of the reactions are inversely proportional to the quality of the radiation. The degree of reaction decreases as the voltage increases for the same dose given.

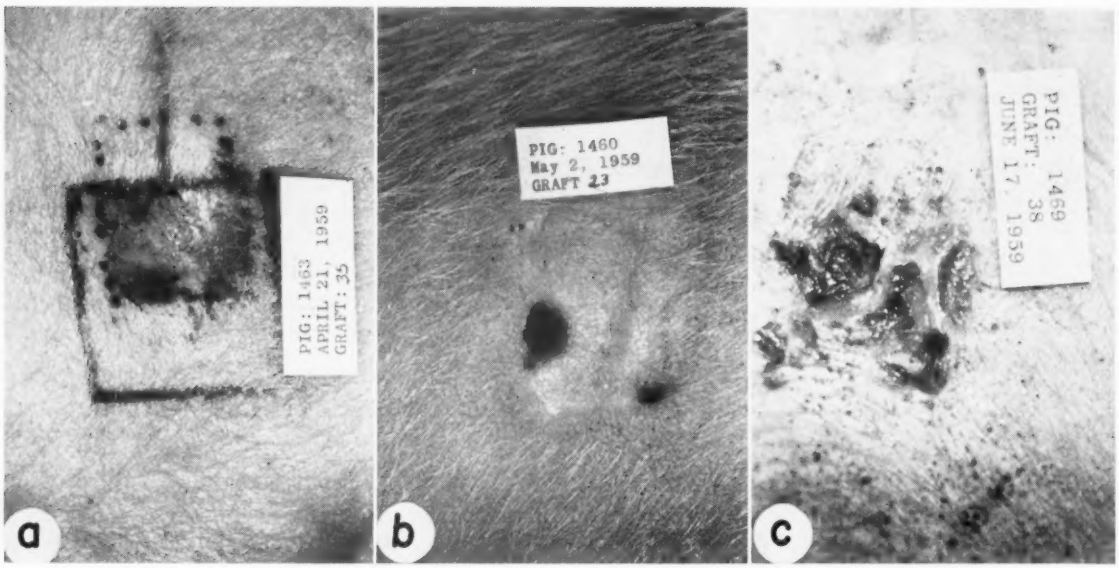

FIG. 4. (*a*) Experiment II, Pig 1463. Graft is defined by dotted line; port is defined by solid line. Increased reactivity of graft as compared to normal skin is demonstrated. (*b*) Experiment III, Pig 1460. One thousand kv. irradiation decreases the difference in reactivity between grafted and normal skin, but what reaction occurs is on graft. (*c*) Experiment IV, Pig 1469. Ulceration of both graft and normal skin at peak of reaction is shown (112 kv.).

vigorously than split thickness grafts, but this was not true in every case so that the individual prediction of a graft's reactivity on the basis of its being either split or full thickness could not be absolutely certain. The recovery sequence after irradiation was not observed due to the death of the experimental animal.

2. *Normal Skin:* In the four weeks after the beginning of irradiation, the normal skin showed no changes. At the death of the experimental animal, four of the irradiated normal skin sites showed no reaction and four showed mild erythema.

In summary, higher energy irradiation as compared to Experiment I, delayed the onset of graft reaction and decreased the severity of graft reaction. Both the quantity of the graft reacting and the quality of the reaction were decreased.

EXPERIMENT III: TO STUDY THE EFFECT OF SUPERVOLTAGE IRRADIATION ON GRAFTS

(Fig. 3*b* and 4*b*)

TECHNIQUE

Four split and four full thickness grafts were irradiated with 1 mev. radiation utilizing a 5 cm. square port at focal skin distance of 55 cm., half value layer 9 mm. Cu. One millimeter of Cu was utilized at the port (50 cm.) as an electron shield. A surface dose, with backscatter, of 2,000 r was administered initially and 1,000 r at weekly intervals, giving a total surface dose of 6,000 r in four weeks to each port.

RESULTS

1. *Grafted Sites:* The grafted areas showed no changes for three and one-half weeks after the beginning of irradiation. Thereafter, small areas of denudation appeared on the graft margins and showed a slight increase in size up to the fifth week. On two full thickness and three split thickness grafts, the areas of denudation remained only scattered and confined to the graft margins. Superficial crusting appeared over the marginal areas of denudation and became no larger than 1 cm. in diameter. On one split thickness and two full thickness grafts, moist desquamation developed on a corner of the graft.

The full recovery phase after irradiation could not be observed due to the death of the experimental animal six weeks after the beginning of irradiation.

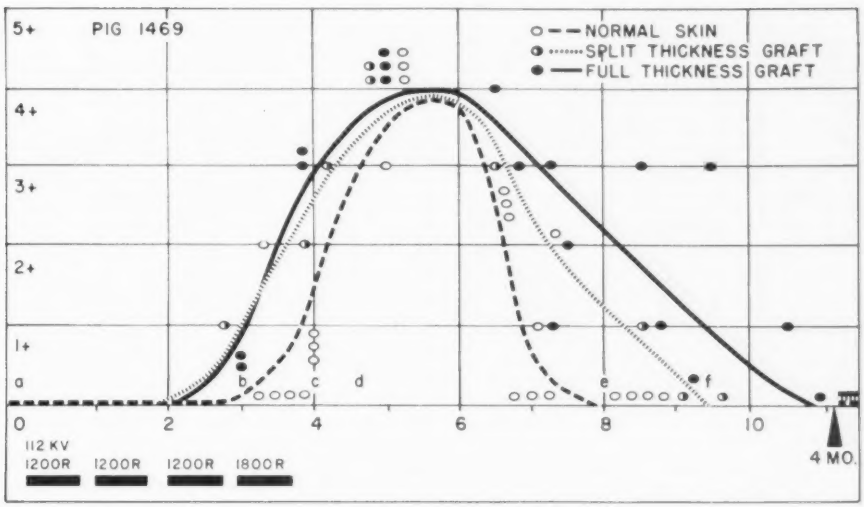

FIG. 5. Experiment IV, Pig 1469. Fractionation of dosage, 300 r daily skin dose, avoids late necrosis of grafts as compared with Experiment I. The response of grafted skin to 112 kv. irradiation was more rapid than of normal skin and the recovery was slower than of normal skin.

2. *Normal Skin:* No reaction on any of the eight sites irradiated could be observed at six weeks.

In summary, supervoltage irradiation further delayed the onset of graft reaction and further decreased the severity (area and depth) of graft reaction. Irradiated normal skin showed no reaction with this schedule of supervoltage irradiation.

EXPERIMENT IV: TO STUDY THE EFFECT OF FRACTIONATION AND PROTRACTION OF DOSE (Fig. 5 and 6, *a–f*)

TECHNIQUE

Two split and two full thickness grafts were irradiated with 112 kv. radiation utilizing a 5.5 cm. (diameter) round port, focal skin distance 20 cm., half value layer 3.7 mm. Al. A daily skin dose of 300 r was administered to each port over a twenty-three day time period giving a total skin dose of 5,400 r to each port. Four grafts on this pig were not irradiated to see if environmental factors played any role in graft changes, not predisposed by irradiation.

RESULTS

1. *Grafted Sites:* Two weeks after the beginning of irradiation (Fig. 6*a*), both split and full thickness grafts began to show small areas of denudation on the graft margins which enlarged with progression to moist desquamation (Fig. 6, *b* and *c*). By the fifth week, the graft reactions had spread centrally to include the whole of the irradiated grafts (Fig. 6*d*). The maximum response at five weeks consisted of ulceration involving all irradiated grafted sites. From the fifth to the tenth week, progressive healing was observed in one full thickness and two split thickness grafts (Fig. 6*e*). Re-epithelization and recovery began in the center of the grafted sites and proceeded toward the graft margins. One full thickness graft showed delayed recovery, but healed in the same pattern. Complete re-epithelization of this graft occurred in the eleventh week, one week later than the other three grafts irradiated (Fig. 6*f*). In a follow-up of six months, no late changes of graft necrosis ensued as in Experiment I.

2. *Normal Skin:* Irradiated normal skin adjacent to graft began to show changes in the third week, one week later than the grafted sites. Moist desquamation spread from the graft margin peripherally into normal skin and proceeded to ulceration in the fifth week. One normal skin site did not react as vigorously and the maximum reaction consisted of moist desquamation. Re-

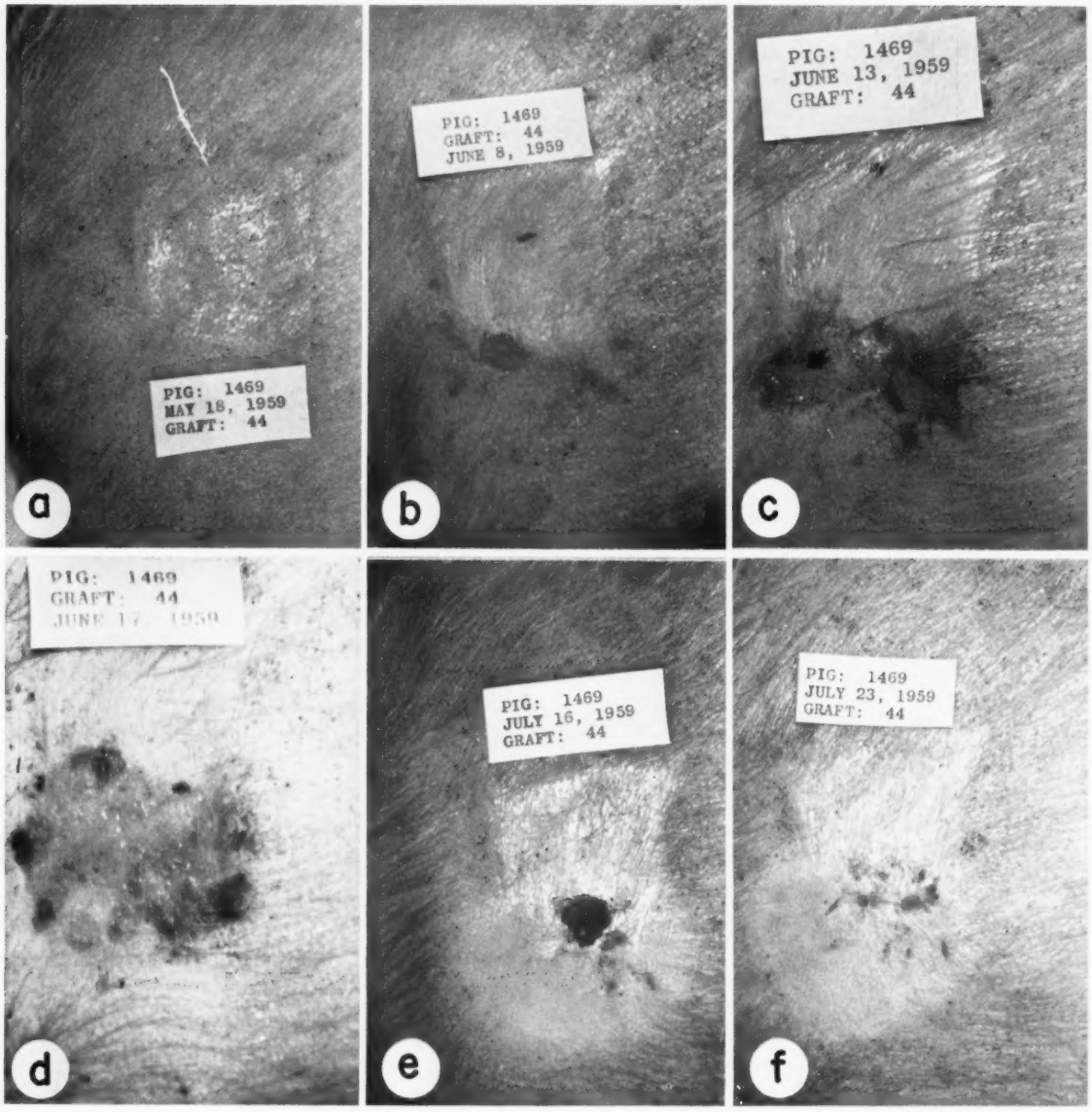

FIG. 6. Experiment IV, Pig 1469. (*a*) Appearance of graft before irradiation. (*b*) Initial reaction is on the graft, at the margin. (*c*) Further progression of reaction involves principally the graft. (*d*) Approaching the peak of reaction, normal skin shows moist desquamation. (*e*) Progressive healing is complete of normal skin; there is delay in graft healing. (*f*) Healing is complete of both normal and grafted skin.

covery of normal irradiated skin was more rapid than of the grafted sites and was completed by seven and one-half weeks in three sites. At eight and one-half weeks, all normal skin sites showed complete recovery. No late changes ensued.

In summary, response of grafted skin to irradiation was more rapid than of normal skin and recovery was slower than that in normal skin. No significant difference between split and full thickness grafts in response and recovery was noted except for the observation that one full thickness graft recovered more slowly. With fractionation of dosage, the severity of reactions was diminished as compared to Experiment I, and late necrosis was avoided. In this experiment, the four autografts not irradiated showed no changes during the entire study.

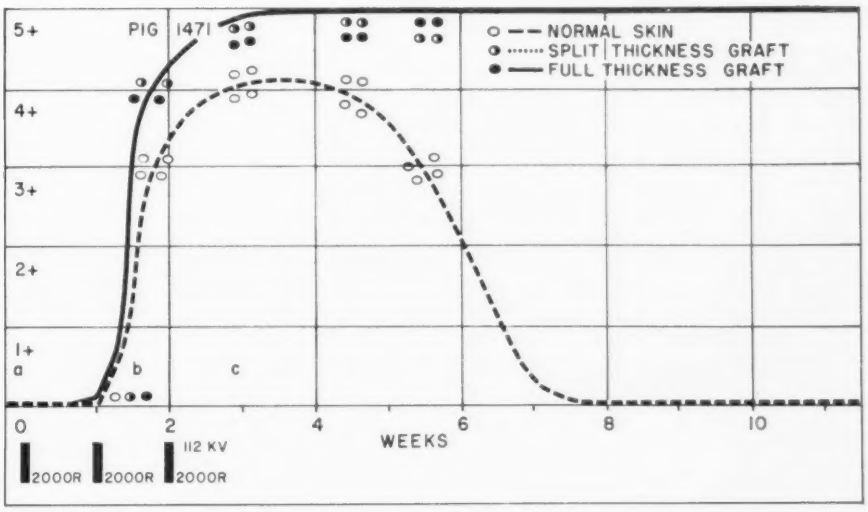

FIG. 7. Experiment V-A, Pig 1471. Study of the role of graft age on its radioresponsiveness. Early graft necrosis was produced on the portion of each graft irradiated, when irradiation was begun the day after grafting. This also occurred in Experiment V-B, utilizing fractionation.

EXPERIMENT V: TO STUDY THE ROLE OF GRAFT AGE ON ITS RADIORESPONSIVENESS

(Fig. 7 and 8, *a–c*)

TECHNIQUE

Since in the previous experiments time was allowed for a good "take" prior to irradiation, it was decided to start irradiation in varying schedules immediately after grafting.

a. Split and full thickness grafts were irradiated with 112 kv. radiation utilizing a 5.5 cm. (diameter) round port at a focal skin distance 20 cm., half value layer 3.7 mm. Al. A skin dose of 2,000 r was administered to each port at weekly intervals, giving a total skin dose of 6,000 r in two weeks. The irradiation was begun on the day after grafting, before the capillary bed was established.

b. Split and full thickness grafts were irradiated with 112 kv. radiation utilizing a 5.5 cm. (diameter) round port, focal skin distance 20 cm., half value layer 3.7 mm. Al. A skin dose of 300 r was administered to each port at daily intervals, 1,500 r per week, giving a total skin dose of 6,000 r in four weeks. Irradiation was begun on the day after grafting.

RESULTS

1. *Grafted Sites:* In both experimental situations, early graft necrosis was produced on the portion of each graft irradiated. With 2,000 r at weekly intervals, necrosis ensued at three weeks; with 300 r daily skin dose, necrosis occurred at four weeks. Every portion of graft *not irradiated* proceeded to a good clinical "take." The margin of graft necrosis was sharply defined by the periphery of the port.

2. *Normal Skin:* Two thousand roentgens at weekly intervals produced moist desquamation with superficial ulceration; 300 r at daily intervals produced only moist desquamation.

In summary, irradiation begun before graft union to host tissues produced necrosis. This occurred even with fractionation in the upper dose range, which is often used with radiation therapy for malignancy.

DISCUSSION

On the basis of the experimental studies and the clinical observations presented, certain conclusions are warranted as to the response and recovery of irradiated grafted skin.

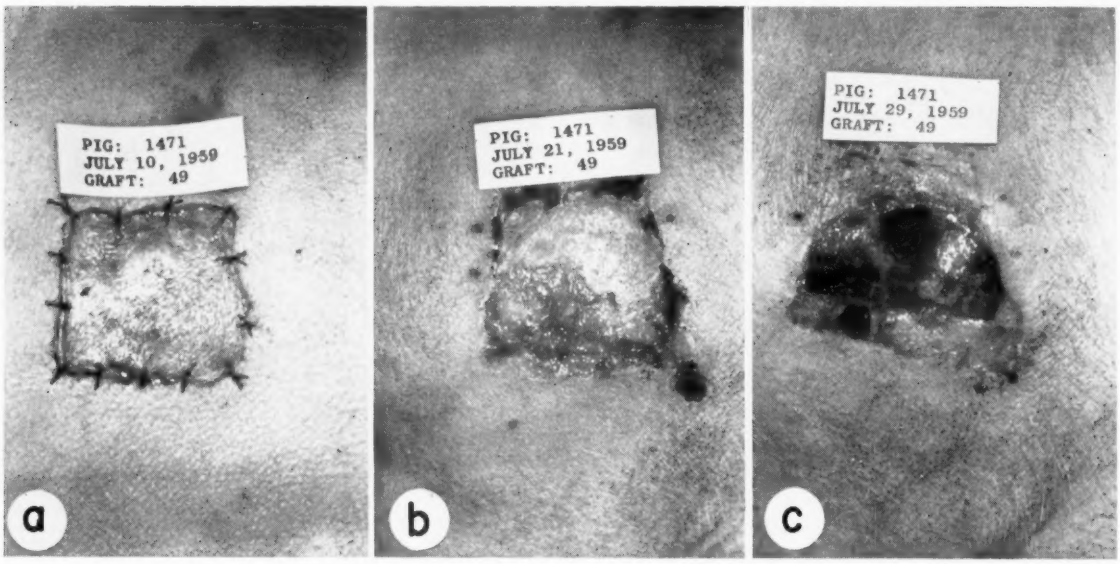

FIG. 8. Experiment V-A, Pig 1471. (*a*) Appearance of graft before irradiation. (*b*) Early severe ulceration of the graft without reaction of normal skin. (*c*) Necrosis of graft is defined superiorly by the periphery of the port and inferiorly by the margin of the graft. Normal skin shows moist desquamation with some ulceration. The same pictorial sequence was obtained in Experiment V-B.

A. *Regarding Response of Irradiated Grafts:*

1. *Fresh grafts react more vigorously and earlier than normal skin to ionizing irradiation.* This is clearly substantiated in all of the experimental studies since exposure to radiation was instituted within two months of autografting. The experimental and clinical observations are parallel. The gross appearance of the graft itself is not a good index of predicting radioresponsiveness; that is, "blanching" of the graft, which occurs four to eight weeks after transplantation, renders it not unlike adjacent normal skin on inspection. Yet, the responsiveness of the graft is greater.

2. *Split thickness grafts react less vigorously than full thickness grafts.* Although this is a good general or average rule, it is not without exceptions. Any specific graft may react over a wide range as illustrated by early deep necrosis of one of the split thickness grafts in Experiment I.

3. *The severity of the reaction is inversely proportional to the quality of the radiation.* This is true for both normal and grafted skin. Fresh grafts, being particularly sensitive, readily show the importance of skin sparing. In reviewing the graphs of the first three experiments, it is obvious that the degree of reaction decreases as the voltage increases for the same dose given. The disparity in response between normal and grafted skin is also less with supervoltage therapy. This would account for the conclusions of Cram *et al.*,[1] in irradiating postmastectomy grafts utilizing Co^{60} therapy.

4. *Fractionation and protraction have less of an impact on response than on recovery.* The onset and severity of the reactions in Experiments I and IV, where different daily exposures were utilized, were about the same; the same total dose delivered in three to four weeks was only at slight variance.

5. *The age of the graft is an important consideration in irradiation.* As shown in Experiment V, starting radiation therapy immediately after autotransplantation can be disastrous. The reaction starts earlier and goes on to necrosis. The sharp demarcation on the graft site between the irradiated and nonirradiated zones rules out secondary factors such as infection, poor surgical application, etc. There can be little

doubt that this is related to suppression of growth of capillaries essential to the viability of the graft.

Although none of the experimental grafts were truly old (past one year), such grafts when encountered clinically failed to respond at all. The recovery phase therefore was not seen. The only clinical instance in which an old graft did react, however, went on to necrosis, suggesting that recuperative powers are quite poor.

B. *Regarding Recovery of Irradiated Grafts:*

1. *In fresh grafts, recovery is delayed* as it takes longer for re-epithelization to take place than in normal skin.

2. *Split thickness grafts recover more quickly than full thickness grafts.* Once again, as in the response to irradiation, considerable overlap exists. The delay rarely averaged more than a week or two weeks at most.

3. *The effect of quality of irradiation* on recovery was not fully evaluated in the experimental studies as the pigs in Experiments II and III died just after the peak of the reaction. In both instances, death was due to the effects of deep irradiation on the bowel. From our clinical experience, it appears that delayed healing as compared to normal skin occurs independently of the voltage employed. Faster recovery, with greater half value layer employed, reflects the degree of reaction produced. If the same degree of response were produced by employing larger doses with supervoltage irradiation, the recovery time would probably be as long as with orthovoltage and superficial radiation.

4. *The value of fractionation is clearly established in aiding full recovery* when the course of the grafted sites in Experiments I and IV are compared. In the first study, full recovery never takes place, with late necrosis of virtually all sites supervening. In the fourth study, complete recovery takes place in all instances. Since the treatment schedules employed clinically are usually more fractionated than those employed experimentally, the likelihood of late necrosis is lessened. This has been borne out by our clinical experience.

5. *The age of the graft determines its ability to recover.* Immediate irradiation after grafting is, as mentioned, quite detrimental. The effect of irradiation on the vascular bed interferes with the viability of the graft and profoundly affects both response and recovery. Waiting for a good "take" is essential as shown by the ability of the grafts to recover in Experiments II through IV as compared to the persistent necrosis produced in Experiment V.

C. *Regarding Therapeutic Implications:*

The therapeutic implications which follow from the data presented indicate that every situation must be handled individually. A set of rules listing indications and contraindications is no substitute for clinical judgment. The most important message to the radiotherapist is that *grafted skin reacts and recovers differently following irradiation than normal skin exposed to similar treatment factors.* This fact *per se* does not mean that radiation therapy should not be employed when a grafted site must be incorporated in a treatment field. It does mean that careful detail to treatment planning should be instituted.

On the basis of the results graphed and documented, certain suggestions are felt to be worthy of consideration.

1. Limit the total dose to a graft as much as possible as is consistent with good treatment.

2. Exclude as much of the graft as possible from the radiation port as is consistent with good treatment.

3. Fractionate and protract the dose as much as is practical since fuller recovery is insured.

4. Employ supervoltage irradiation because the skin sparing effect thereby lessens the severity of graft reaction.

5. Allow for a good "take" of the autograft rather than beginning irradiation immediately. Usually, this is within three to four weeks after grafting.

Other factors which are of lesser importance and predictability are thickness of

the graft, lower voltages, and the role of infection. It is difficult to state what advantages a split thickness has over a full thickness graft in regard to irradiation. Although the split thickness graft seemed to tolerate the dosages employed experimentally somewhat better, it has a wider range of response. This is further amplified in the paper dealing with the vascular pathophysiology of irradiated grafts.[2] From a pragmatic point of view, once a good "take" is established, the risks are about the same. The difference between orthovoltage and superficial therapy is probably less critical than the difference between orthovoltage and supervoltage therapy. The role of infection is no greater in causing the skin erythema on grafts than on normal skin. Meticulous hygiene is advised to avoid secondary bacterial problems.

SUMMARY

1. An experimental program was evolved to study the following variables when irradiating skin grafts: (a) The quality of the radiation; (b) fractionation and protraction of dose; (c) the age of the graft; and (d) the thickness of the graft.

2. From the results of these studies and the clinical observations noted, an analysis of tolerance based on response and recovery patterns is presented.

3. The therapeutic implications of these studies are listed as a guide to the radiotherapist in the hope of increasing the tolerance of irradiated grafts.

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THE VASCULAR PATHOPHYSIOLOGY OF AN IRRADIATED GRAFT*

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THE difference in the vascularization of normal skin and grafted skin forms a reasonable basis to explain the differences in radiation reaction of these structures. The role of the vascular bed in radiation response has been reviewed on numerous occasions. Careful clinical observations and experimentation have clearly shown that, in a wide variety of circumstances, alteration in capillary anatomy and physiology has a profound effect on irradiated tissue and tumor.

Grafted skin studies involving irradiation are no exception. In 1937, Ungar and Warren[12] gave proof to this concept when they reported the effects of irradiated epithelium and stroma on "takes." They found that irradiated epithelium was able to grow when transplanted to normal corium with a frequency of 32 per cent, while normal epithelium always failed to grow when transplanted to an irradiated stromal bed. Further studies on the indirect irradiation effects with skin grafting by Jolles and Greening[4] corroborated the work of the aforementioned authors. More recently, Sargent,[10] in a variety of experimental situations in rats, demonstrated that the vascularity of the stromal bed determines the success or failure of autotransplants when irradiated massively.

To appreciate the thesis of this paper, knowledge of the changing blood supply pattern of an autograft is essential. A brief review of current concepts[1,8] of the histologic changes following transplantation of skin therefore follows.

HISTOLOGIC CHANGES FOLLOWING AUTOGRAFTING

(1) *Stage of Plasmic Circulation* (Fig. 1). Within a few minutes after transplantation, the blood vessels of the host in contact with the graft dilate; the dilatation is followed by an exudation of plasma. A fibrinous network anchors the graft to its bed and, in twenty-four to forty-eight hours, budding host endothelial vessels start to penetrate this matrix.

(2) *Stage of Vascularization* (Fig. 2). In the course of the first few days, delicate vessels in the form of endothelial tubes arise from the capillary loops of the host and grow into the graft, sometimes joining directly with its severed capillaries. This process is usually established by the third day with signs of active proliferation of epithelium beginning in the implant. Capillary vascularity in the new graft rapidly exceeds the vascularity of normal skin.

(3) *Stage of Organic Union* (Fig. 3). This stage occurs when gradual replacement by a layer of fibroblasts and collagen in the graft bed diminishes capillary vascularity of the graft to that approximating normal skin. An established blood supply appears to be present on the third to fifth day as shown by the pinkish color of the graft; graft union is firm by the tenth day and blanching due to ingrowth of

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‡ The contents of this article are the personal views of the Air Force author and are not to be construed as statement of official Air Force policy.

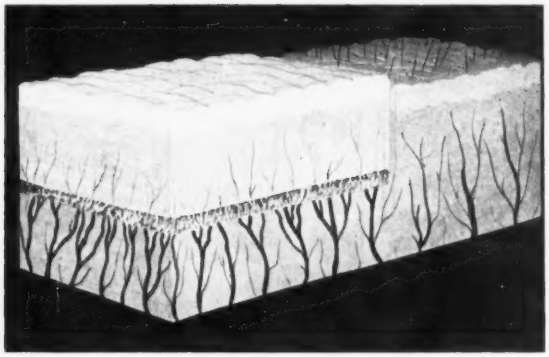

FIG. 1. Stage of Plasmic Circulation.

collagen starts during the second or third week.

(4) *Stage of Contraction* (Fig. 4). With the ingrowth of fibroblasts and collagen, scarring and contraction take place in the months to follow, varying with the thickness of the graft, the location of the recipient area, and the completeness of the "take." In full thickness grafts, there is less fibrosis and contraction is rarely in excess of 10 per cent of the original area, whereas split thickness grafts may decrease to as much as 50 per cent of their initial size. This contraction is not caused by the graft, which is composed principally of epithelium, but is due to the cicatrization of the base upon which it is placed. It is this cicatrix which blanches the graft and makes it more ischemic than the surrounding normal skin. After one year, this process is essentially completed.

PHYSIOLOGIC STUDIES

With this as background information, it

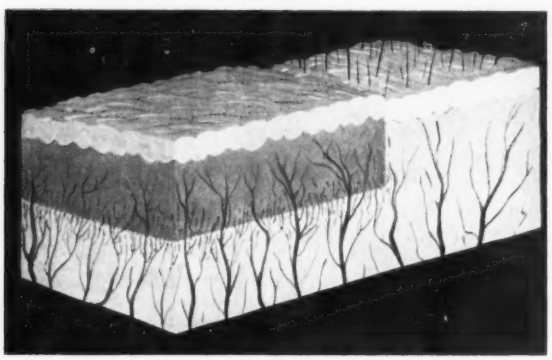

FIG. 2. Stage of Vascularization.

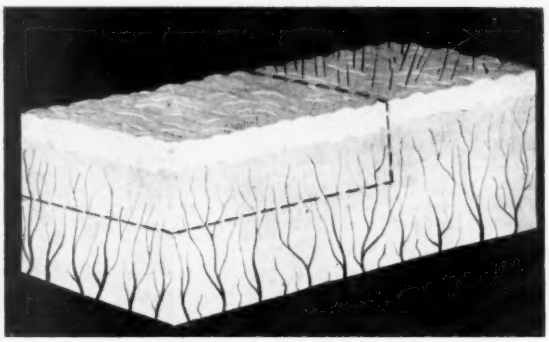

FIG. 3. Stage of Organic Union.

is logical to anticipate that the more vascularized a graft is, the more sensitive the graft will be to irradiation. A physiologic measure of the graft's vascularity is of vital importance and may serve as a reliable index for predicting radioresponsiveness. A recognized method of studying vascular integrity[7] is the injection of small quantities of radioisotopes intradermally and subcutaneously and observing the disappearance rate from the local site. Lymphatic drainage plays no significant role in the local removal of crystalloid isotopes as shown in experiments in which the thoracic duct and major venous drainage channels were cannulated.[11]

TECHNIQUE

Briefly, the technique employed in the material presented is as follows:

(a) One tenth (0.1) cc. of NaI^{131} is injected subcutaneously in a normal skin site and in the graft under study.

(b) A twin probe rate-meter-recorder unit is employed and simultaneous plots of

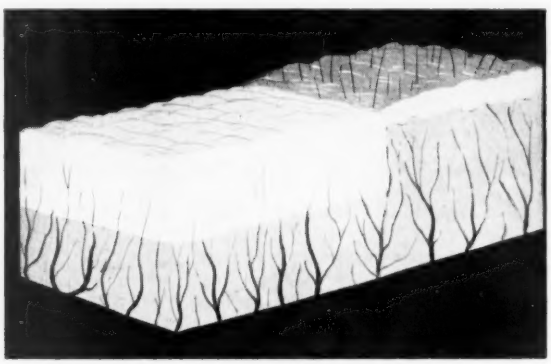

FIG. 4. Stage of Contraction.

the disappearance rates of the radioisotope are graphed from both sites.

(c) The recorded information is then replotted on semilog paper since the rate of disappearance is exponential within biologic limits.

(d) By measuring the rate rather than the amount of radioisotopic absorption, the half time of disappearance can be used as an expression of the vascularity of the site injected. Measurements in each of the stages of graft union were done whenever possible in both clinical and experimental circumstances prior to irradiation.

RESULTS

Typical illustrations of the data are presented.

(1) *Stage of Plasmic Circulation* (Fig. 5). Pig graft on the first day following transplantation, prior to the ingrowth of new vessels, showed a slower disappearance of NaI^{131} in the grafted site as compared to the control skin. Deep anesthesia of pig prolongs normal skin control.

(2) *Stage of Vascularization* (Fig. 6). R.S., a sixty-three year old male requiring a split thickness graft following excision of a squamous cell carcinoma of the right malar eminence, was studied two weeks postoperatively. The increased half time disappearance of the radioisotope in the graft was comparable to that in pig autografts studied from the third day up to three months after autografting.

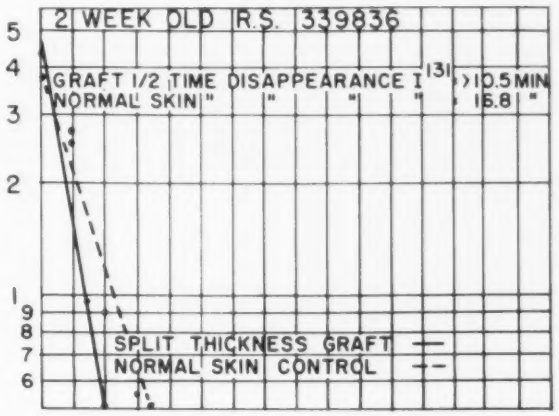

Fig. 6. Example of Stage of Vascularization.

(3) *Stage of Organic Union* (Fig. 7). H.Z., a forty-eight year old woman, had a full thickness skin graft placed in her left popliteal fossa after excision of a malignant melanoma. Prior to irradiation, which was done six months later for recurrent skin metastases, an I^{131} injection study was done. The disappearance of I^{131} from the local injection site of the graft paralleled the disappearance of I^{131} from the normal skin control. This is representative of the transition in vascularity from a fresh graft to an old one. During the midspectrum, the vascularity of the graft and the normal skin are the same. This period clinically extends approximately from the third month to the first year following transplantation.

(4) *Stage of Contraction* (Fig. 8). M.F., a sixty-nine year old white female, required a split thickness graft for closure after a

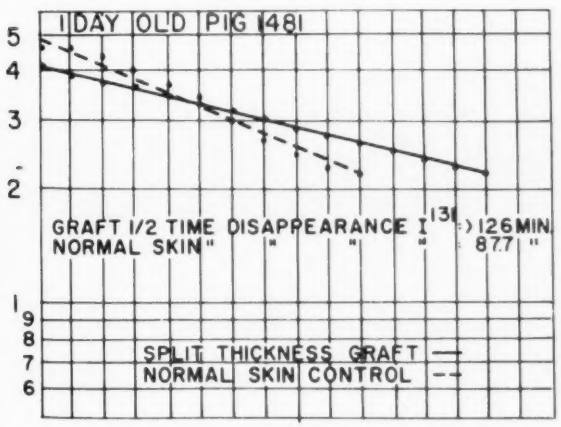

Fig. 5. Example of Stage of Plasmic Circulation.

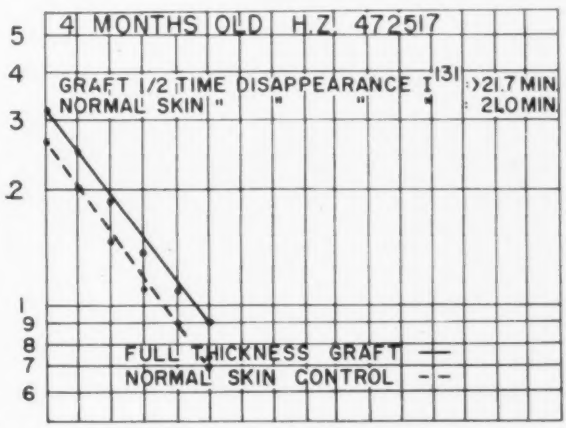

Fig. 7. Example of Stage of Organic Union.

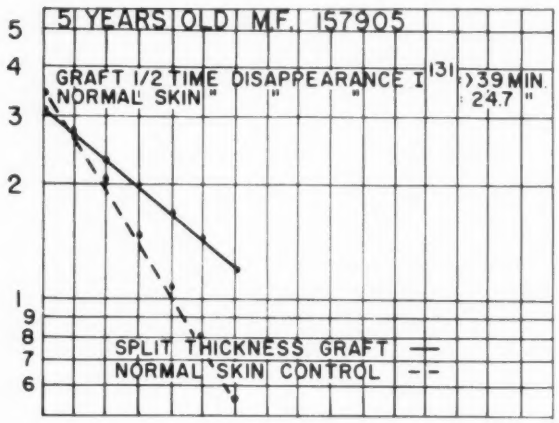

FIG. 8. Example of Stage of Contraction.

left radical mastectomy. When I^{131} subcutaneous injection was done, the graft was five years old. The half time disappearance was significantly slower than in normal skin.

These examples strikingly demonstrate the profound vascular changes that occur with union and subsequent aging of the graft. In Table 1, the various graft studies are arranged chronologically according to the graft age. The necessity for each patient and animal to serve as its own control is apparent, since the physiologic conditions are different in each case; *i.e.*, temperature, blood pressure, pulse rate, anesthesia, humidity etc., and the disappearance rate from normal skin will vary.

From these data, the following generalities are derived:

1. In the *Stage of Plasmic Circulation*, the graft half time of radioisotope disappearance is *longer* than in the normal skin control.

2. In the *Stage of Vascularization*, the graft half time disappearance is appreciably *shorter* than in the normal skin control.

3. In the *Stage of Organic Union*, as the increased vascularity of the new graft is gradually diminished, the half time of radioisotope disappearance *approximates* that of normal skin.

4. In the *Stage of Contraction*, the half time disappearance in the grafted skin is significantly *longer* than in the normal skin.

The conclusion is that the half time disappearance measures the physiologic stage (or age) rather than the chronologic age of the graft. This test also reflects the vascular status of the graft and serves as an index of its radioresponsiveness.

PATHOLOGIC CHANGES

The microscopic changes correlate with the macroscopic events following irradiation. These observations were limited to the pig autografts, but it is reasonable to apply the derived information to man. Biopsies taken at the initial phase of the radiation reaction in the graft, one week after the site received 6,000 r, showed the following histologic changes:

Normal Skin. Grossly, a one plus erythema was noted. Tissue sections showed congestion and dilatation of subepidermal capillaries and some damage to arterioles. The epidermis was atrophic.

Grafted Skin. The gross appearance was that of a three plus reaction or moist epithelitis. Pathologic changes were those of denudation of epidermis and ulceration of dermis. In the dermis, considerable arteriolar damage and evidence of new vasculature formation with little blood were seen, except for occasional congested vessels filled with erythrocytes. Areas of hemorrhage into dermis were also seen.

Further studies twenty weeks after irradiation, at the time of deep necrosis, showed the following changes:

Normal Skin (Fig. 9*A*). Grossly no reaction was observed, but microscopically residual arteriolar damage was seen in the dermis.

Grafted Skin (Fig. 9*B*). Macroscopically deep necrosis and ulceration (five plus reaction) were seen. Severe necrosis and ulceration with marked inflammation in the form of lymphocytes were noted on sections. Throughout the dermis tremendously increased formation of new vessels was apparent; some capillaries were congested and others contained no blood. A "histohematic barrier" would seem to be present on the basis of associated heavy fibrosis.

Microscopic studies in a variety of situa-

TABLE I

VASCULAR CHANGES IN AUTOGRAFTS USING THE I^{131} HALF TIME DISAPPEARANCE RATE TEST*

Subject	Chronologic Graft Age	Physiologic Age (Stage)	Disappearance Rate (min.)			
			Split Thickness Graft	Full Thickness Graft	Relative Value	Normal Control
1481	1 da.	Plasmic Circulation		+114	>	87
1481	1 da.	Plasmic Circulation	+126		>	87
1481	3 da.	Plasmic Circulation		99	>	88.5
1481	3 da.	Vascularization	39		<	63.7
1481	5 da.	Vascularization	28.5		<	72.7
1481	5 da.	Vascularization		60.7	<	73.5
Shelters	2 wk.	Vascularization	10.5		<	16.8
Katron	4 wk.	Vascularization	7.5		<	16.5
1470	4 wk.	Vascularization		30	<	66.7
1470	4 wk.	Vascularization	39.7		<	50.2
1469	10 wk.	Vascularization	33.7		<	50.2
1470	11 wk.	Vascularization		18	<	51
1469	11 wk.	Vascularization	21		<	60.7
1469	12 wk.	Vascularization		36	<	69
UpDyke	3 mo.	Organic Union	10.5		=	9
UpDyke (2)	3 mo.	Organic Union	10.5		=	9
Zucker	5 mo.	Organic Union		21.7	=	21
1469	5 mo.	Vascularization		24.7	<	42.7
1469	5 mo.	Vascularization		11.2	<	16.5
1469	5 mo.	Organic Union		12.7	=	13.5
1469	5 mo.	Organic Union	15.7		=	18
1469	5 mo.	Organic Union	16.2		=	15
1469	5 mo.	Cicatrization	27		>	19.5
1469	5 mo.	Cicatrization	30		>	15
1469	5½ mo.	Vascularization		24	<	63.7
1469	5½ mo.	Vascularization		23.2	<	33.7
1469	5½ mo.	Vascularization	47.2		<	57
1469	5½ mo.	Cicatrization	42		>	26.2
Sullivan	5½ mo.	Cicatrization	31.5		>	15
Goldman	18 mo.	Cicatrization	16.5		>	10.5
Ferrara	5 yr.	Cicatrization	39		>	24.7

* Numbered subjects are pigs. The physiologic age or stage of the graft is interpreted from the injection I^{131} study. The longer normal controls of pig subjects reflect the depth of anesthesia and decreased circulation time.

tions showed similar vascular changes in irradiated graft sites as compared to the nonirradiated grafts. These changes were less pronounced with fractionation schedules. Similar changes were seen in irradiated normal skin sites and grafts but are difficult to quantitate as to severity without tedious counting and no comparison on this basis is offered.

DISCUSSION

In conceptualizing about the spectrum of reactions of grafted skin to ionizing irradiation, knowledge of the radiopathologic changes in capillaries must be utilized with knowledge of the histophysiologic state of the vascularity of the graft.

A. *Irradiation during Stage of Plasmic Circulation*, prior to union of the graft, produces suppression of the new capillary budding from the host vascular bed which is essential to graft survival. The inability of irradiated vessels to form new capillaries has been shown by Merwin, Algire, and Kaplan[5] in their transparent chamber techniques by the inability of an irradiated bed to vascularize tumor implants. The early and persistent necrosis in our experi-

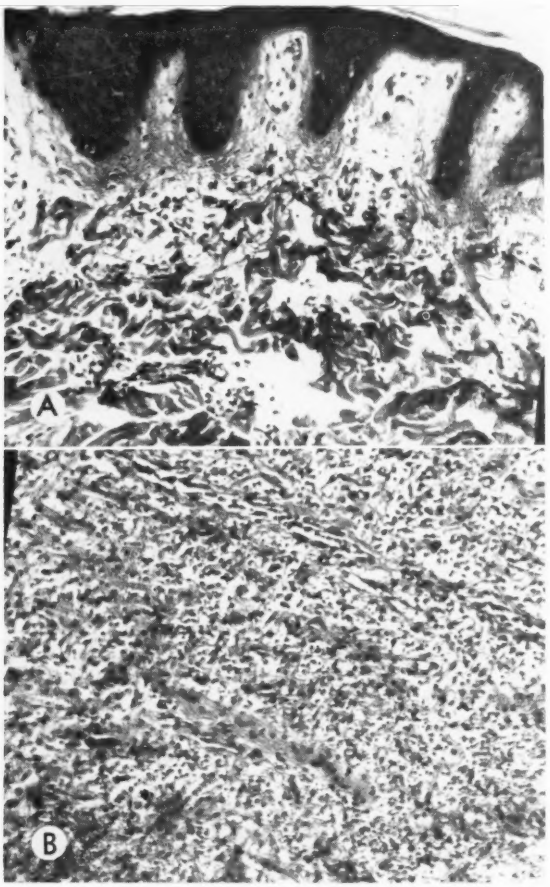

FIG. 9. (A) Radiation changes in normal skin at twenty weeks. Grossly, there was no reaction, but microscopically residual arteriolar damage was seen in the dermis. (B) Radiation changes in grafted skin at twenty weeks. Throughout the dermis, tremendously increased neoformation of vessels was apparent; some capillaries were congested and others contained no blood. A "histohematic barrier" would seem to be present on the basis of associated fibrosis.

mental studies (Experiment v[3]) is readily understandable.

B. *Irradiation during Stage of Vascularization* will elicit a greater reaction in the graft by virtue of the excessive capillary sprouting and ingrowth of vessels. In the first few weeks to few months following successful transplantation, the sprouting and ingrowth of vessels endow the graft with abundant channels to gather its nutrition. As in reaction to injury, *i.e.*, wound healing, the vascularity of granulation tissues is excessive initially and then returns to normal. In fresh grafts, arbitrarily defined as those up to three months of age, the erythema is brisker and occurs earlier than in normal skin exposed to the same dosage factors (Cases IV, V, and VI, in our report of clinical observations[9]). The delay in repair at this stage may be explained by the observations of van den Brenk[12] who placed transparent chambers in rabbits' ears to study the effect of irradiation on capillary sprouting. He draws attention to "the indirect effects of fibrillogenesis (fibrous barrier formation) on halting capillary regeneration and remodelling despite an intrinsic competence for growth of the irradiated vascular component." The morphologic events described by this author can be seen in our serial biopsy studies. The microscopic findings of excessive angioblastic formation resulting in a cavernous hemangioma type appearance in an area of late necrosis parallel the radiation phenomenon of "super-regeneration" of Litschko;[13] *i.e.*, the intrinsic competence for growth of irradiated endothelium remains intact though temporarily impaired following a threshold level of irradiation. The formation of a fibrous barrier, however, impairs vascular lability and results in a histohematic barrier with necrosis supervening (Experiment I[3]).

C. *Irradiation during Stage of Organic Union* evokes a reaction in the graft approximating that in normal skin. As the graft matures, its resemblance to normal skin increases. The gross pink appearance gradually blanches and physiologically and histologically it reacts as does normal skin to irradiation. This period of transition extends from three months to one year. It is worth noting again that this stage is arbitrarily assigned in sequence to that of vascularization, but in actuality begins almost simultaneously.[2] In split thickness grafts, according to Miller and Hinshaw,[6] the fibroblastic response is much greater as a rule than in full thickness grafts. This causes shrinkage and also reduces vascularity more rapidly and in another sense ages the graft earlier. This may explain the decrease in responsiveness and the rare but occasional unpredictability in the reaction

to irradiation of split thickness as compared to full thickness grafts (Experiments I, II and III)[3].

D. *Irradiation during Stage of Contraction or Cicatrization* will usually evoke no response in the graft, since vascularization is less than in normal skin and scar tissue is relatively radioresistant. In time (usually after one year) the graft appears more white and atrophic than the normal surrounding skin and cicatrization is reflected in the retraction of the graft below the normal skin surface. The reduced vascular index at this stage has been demonstrated by radioisotopic injection. The relative ischemia tends to protect the graft against the effects of radiation. Doses which usually elicit a desquamative reaction in normal skin produce little erythema in the grafted site. If a reaction is elicited, the decreased vascularity may sufficiently compromise recovery powers so that necrosis may ensue; *i.e.*, thrombosis of existent capillaries may be sufficient to upset the already compromised circulation. The state of connective tissue stroma may also contribute to necrosis as irreversible hyalinization and the histohematic barrier common to atrophic tissues may be accelerated by irradiation.

CONCLUSIONS

The value of the radioisotopic half time of disappearance as an index of vascular integrity of the graft has been demonstrated. It is a measure of the physiologic age rather than the chronologic age of the graft. Using a normal skin site in a similar anatomic area as a control affords one a base line value for comparison. The radiation response tends to be proportional to the disappearance rate; *i.e.*, the faster the rate, the greater the reaction. Since a spectrum of responses can be anticipated, the value of this test as an index for predicting the radioresponsiveness of grafts when they must be incorporated in treatment fields is apparent. This is of particular value in defining the state of vascularity in split thickness grafts.

With the advent of more radical surgery for carcinoma, reconstructive procedures are increasingly utilized. Postoperative irradiation for residual disease early in the life of an autograft and later for recurrent carcinoma is not uncommon. An understanding of radiopathologic changes in other tissues used for grafting would be worth investigating. Such tissues as cartilage, tendons, fascia, large vessels, and cornea are relatively avascular and probably would withstand irradiation at a graft site, once a good "take" was established, as well as at the original site. In the special case of the cornea, excessive vascularity following transplantation is detrimental to the success of the graft. Radiation in the form of a beta plaque is frequently used to destroy such neovascularization to prevent clouding of the new cornea. In bone grafts, as compared to the other tissues mentioned, the host tissue infiltrates an autogenous graft and actually replaces the graft structure, so that it resembles the original tissue. This is an instance of cellular replacement[8] as opposed to cellular survival of other tissue grafts. Irradiation *in vivo* may in this instance compromise a good result. Curiously, large dose irradiation of bone grafts *in vitro* prior to grafting for bacterial sterilization has a beneficial effect indirecly on the ultimate success of bone grafting.

In bone marrow transplantation, total body irradiation to suppress the immune mechanism is being carefully studied. Other homografts such as skin and kidney have been tried and studied in special circumstances following total body irradiation. The pathophysiology in such circumstances is beyond the limits of the present thesis, however, but it serves to emphasize the rapid changes occurring in medicine and the ever-widening horizons of the radiotherapist. The subjects of irradiation and tissue grafting, though seemingly unrelated, touch on many levels.

SUMMARY

1. The difference in the vascularization of grafted and normal skin forms a reasonable basis for explaining the differences in the radiation reactions of these structures.

2. The radioisotope half time of disappearance following subcutaneous injection is an index of vascular integrity of the graft and serves as a parameter to predict its radioresponsiveness.

3. In developing a concept of the spectrum of reactions of grafted skin to ionizing irradiation, knowledge of the radiopathologic changes in capillaries must be utilized with knowledge of the histophysiology of the vascularity of an autograft.

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Forty-third Annual Meeting: Broadmoor Hotel, Colorado Springs, Colo., May 11–14, 1961.

* *Ex officio.*

EDITORIAL

THE FORTY-SECOND ANNUAL MEETING OF THE AMERICAN RADIUM SOCIETY

THE American Radium Society held its Forty-second Annual Meeting in the tropical setting of San Juan, Puerto Rico, on March 17, 18 and 19, 1960 at the attractive and comfortable Caribe-Hilton Hotel. The attendance by members and guests was unusually good, in spite of the extended distance of the meeting place from the United States. The total registration was 414, representing 118 members, 155 nonmember guests and 141 ladies. Dr. Victor A. Marcial, chairman of the arrangements committee and the only local member welcomed the Society to its first meeting on this delightful island territory. Before delivering his Presidential Address, Dr. Theodore R. Miller notified the Society that it had been fortunate in securing generous grants from the Radium Chemical Company, the American Cancer Society, and the Atomic Energy Commission of the United States, thus enabling the Society to invite distinguished speakers from abroad which, it is hoped, will lead to a profitable exchange of ideas.

Dr. Miller chose for his address the interesting subject, "Training of the Cancerologist." He indicated that about seventy per cent of the cases seen in the cancerologist's practice had received previous treatment and that many had been poorly managed because of the inadequate training of the physician in the field of cancer. Cancer is one of the few diseases in which early diagnosis and prompt and proper treatment make the difference between life and death. The great significance of the biologic approach to cancer therapy is embodied in the principle that the cancerologist should have the knowledge of the standard procedures in cancer surgery, a familiarity with the effect of ionizing radiations and an understanding of the chemotherapeutic and hormonal approaches. The unique character of the American Radium Society, in reality the oldest national scientific society primarily interested in the treatment of cancer, places it in the position to influence the trend of postgraduate medical education. It is a vital function of this Society, through its members, to train men so that a broad knowledge of cancer is acquired, and consequently better understanding and better treatment of the cancer patient.

The first scientific session followed Dr. Miller's address with a presentation of papers dealing with a variety of subjects, Dr. Lemuel Bowden acting as chairman. Dr. Gioacchino Failla discussed data relating to the impact of radiation and modern medicine on longevity. Life span he feels can only be extended by changing mutations in some way. Dr. Philip Rubin gave statistics on the incidence of pelvic cancers following irradiation for benign gynecologic conditions and stated that the predisposing condition rather than the irradiation is the etiologic factor in the number of gynecologic cancers noted. Other papers dealt with Co^{60} irradiation and surgery in the treatment of bronchogenic carcinoma; skin and subcutaneous reactions induced by supervoltage irradiation; the use of Ca^{47} in diagnostic studies of patients with bone lesions; the effects of therapy and survival in 1,269 patients with lymphosarcoma over a period of thirty years; and a clinical evaluation of survival statistics in carcinoma of the cervix from five to ten

years after radiation therapy.

The first George H. Loftus Memorial Lecture, made possible by a grant from the Radium Chemical Company, was delivered by Dr. Sven Hultberg, Director of Radiumhemmet of Stockholm, Sweden, who outlined the recent methods of treatment of oral cancer at that institution. Since 1954, the emphasis has been on telegamma therapy with a Co^{60} source as contrasted to previous methods of radium bomb and interstitial applications. Painstaking planning is employed in order to obtain more exact dosage patterns for lesions located from 1 to 6 cm. below the skin. Individualization of treatment is practiced by the construction of a wire jig for each patient in order to locate the multiple fields to be used in the sliding technique. The dosage ranges from 5,500 to 6,500 r in a period of eighteen to twenty-four days. Dr. Hultberg gave a detailed account of five and ten year survivals of various intraoral cancers. The end results show an appreciable increase over former statistics and now fall in the 35 to 40 per cent range.

The social event of the first day, a beach party and picnic sponsored by Abbott Laboratories, was held in the afternoon at Luquillo Beach, about twenty miles from San Juan. Swimming in the warm Atlantic Ocean with a backdrop of white sandy beaches and tropical royal palms, delicious native food and music by a group of native performers playing on a variety of steel drums delighted the members and guests.

The second scientific session on Friday morning was moderated by Dr. Gray H. Twombly. The first presentation was on successful results of radiation treatment of cancer of the mouth, larynx and pharynx during a twenty-two year period at Memorial Hospital from 1931 through 1952 by Dr. Daniel Catlin. In the next paper, a study of the treatment of cervical cancer and radioresistance, Dr. Alfred I. Sherman documented the fact that error in placement of the radium sources was the main cause of failures rather than resistance of the neoplasms. Dr. Manuel Lederman of the Royal Marsden Hospital of London presented the results of radiotherapy of malignant melanomas of the eye and showed that some conjunctival and limbal melanomas are radiosensitive. Patients with these lesions have a good prognosis and the affected eye need not be lost.

One of the highlights of the Annual Meeting is the Janeway Lecture. Dr. Edith H. Quimby, in introducing Dr. William S. MacComb of Houston, Texas, this year's Janeway Lecturer, related some of the events in Dr. MacComb's career which led him into the cancer field, first at Memorial Hospital in New York for a period of seventeen years and then at the M.D. Anderson Hospital in Houston, Texas since 1952. Dr. MacComb reviewed the early surgical and radiotherapeutic history of the treatment of cancer. He recounted the trial and error methods of both surgery and radiation therapy and the swing of the pendulum over the past fifty years. Following World War II, with the improvements in anesthesia and the effects of antibiotics on infections, a new surgical era appeared and the limits of the operative field widened. Older procedures were renewed with greater success and many combined procedures were now possible. Dr. MacComb, in great detail, then discussed the management of the various types of head and neck cancers, giving indications for surgery, irradiation and combined procedures in the proper order of application. Emphasis was placed on the importance of close cooperation between the cancer surgeon and the radiotherapist.

The morning program continued with presentations on the relative biologic effectiveness of Co^{60} versus 250 kv. photons as determined by the hela cell; the clinical use of a short source-skin distance cesium 137 unit; *in vivo* miniature glass dosimetry; and on hypnosis and its uses in controlling cancer patients. At the close of the session, guest speaker Dr. Carl-Axel Hamberger, Head of the Department of Otolaryngol-

ogy, Sahlgrenska Hospital, Gothenburg, Sweden, related his experiences with trans-antro-sphenoidal hypophysectomy. He presented in detail the technique of approach and removal of the hypophysis for treatment of mammary cancer and acromegaly.

In the afternoon of the second day, a fashion show was held in the hotel for all members and guests. Later, in the early evening, a social hour was sponsored by the International General Electric Company of Puerto Rico and Atomic Energy of Canada, Ltd. The annual banquet followed in the beautiful Club Caribe. Dr. Theodore Miller, with appropriate ceremony, presented the Janeway Medal to Dr. William S. MacComb.

The third scientific session began on Saturday morning with Dr. Jesshill Love acting as chairman. Dr. Sidney Silverstone read a paper prepared by workers at Oak Ridge on leukemia induced by radiation. A study of cancer of the cervix survivors who had received radium treatment indicated that the incidence was no greater in these persons than in the general population. Dr. Harold W. Dargeon in his paper on lymphosarcoma in children showed that pessimism had lessened in the past ten years in regard to the management of malignant tumors in children. The latter half of this session was devoted to a colloquium on modifiers of radiotherapeutic response in patients, moderated by Dr. James J. Nickson. Dr. L. H. Gray of Middlesex, England, pointed out the influences of oxygen tension on the quantity of human cancer cells following exposure to ionizing radiation. Dr. William B. Seaman spoke on oxygen pressure chambers now being used in experiments to determine the effects of irradiation on humans under several atmospheres of pressure. Dr. Malcolm A. Bagshaw of Stanford pointed out the influence of various cytotoxic compounds on the irradiation effect in man. Dr. Harvey Patt of the Argonne National Laboratory elucidated the effects of a wide variety of chemicals used as protective measures in irradiated organisms.

The Forty-second Annual Meeting of the American Radium Society at San Juan was indeed a success. Dr. Victor Marcial's gracious hospitality, the organization and caliber of the scientific contributions and the semitropical surroundings will long be remembered by those who attended.

HARRY HAUSER, M.D.

SOCIETY PROCEEDINGS AND NEWS ITEMS

VI SYMPOSIUM NEURORADIOLOGICUM

The next International Congress of Neuroradiology (VI Symposium Neuroradiologicum) will be held in Rome, Italy, September 18–22, 1961, under the Presidency of Dr. Giovanni Ruggiero. A program is being arranged which will include scientific meetings, scientific-technical exhibits and social activities. Several tours are planned which will prove of interest to visitors. The Committee of the VI International Congress of Neuroradiology extends a warm and sincere welcome to members of radiological societies.

All correspondence should be addressed to Dr. Enzo Valentin, General Secretary, VI Symposium Neuroradiologicum, CIT—Ufficio Congressi—p. Colonna 193, Rome, Italy.

ORNL AND ORINS SPONSOR CONFERENCE

The nuclear reactor on the university campus will be the subject of a conference to be held in Gatlinburg, Tennessee, August 17–19, 1960.

The conference will be sponsored by Oak Ridge National Laboratory and the Oak Ridge Institute of Nuclear Studies, in cooperation with the Oak Ridge section of the American Nuclear Society and the Atomic Energy Commission.

University scientists will discuss various problems related to university reactors. Under consideration will be the present status of university reactors in the world today, and the uses to which they are being put for education and training, as well as for research; criteria for determining a university's need for a particular type of reactor; characteristics of university reactors; methods of procuring and staffing a reactor project; and the availability of university reactors from industry.

An opportunity for a reactor tour at Oak Ridge National Laboratory will be provided for the conference participants.

Further information concerning this conference is available from the University Relations Division, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tennessee.

We regret to announce the death on April 26, 1960 in Syracuse, New York, of Dr. Donald S. Childs, distinguished member of the American Roentgen Ray Society and Secretary-Treasurer and Business Manager of the Radiological Society of North America and of its official publication, *Radiology*, for many years; also, the death on April 25, 1960 in Louisville, Kentucky of Dr. Joseph C. Bell, distinguished member of the American Roentgen Ray Society and Past President of the Radiological Society of North America.

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

AMÉLIORATION ET REPRODUCTION DES RADIOGRAPHIES PAR MODULATION ÉLECTRONIQUE; LE LOGETRON. By A. Jutras, Professeur de Radiologie, Université de Montréal; and H. Fischgold, Neuro-Radiologiste de l'Hôpital de la Pitié, Paris. Paper. Price, $9.00. Pp. 122, with 16 illustrations. Masson et Cie, Editeurs, 120 Boulevard Saint-Germain, Paris 6e, France, 1958.

This monograph is devoted to a study of the LogEtron and its applications to radiology. The LogEtron has been devised in order to properly record the extreme density ranges present in a negative. It has been used with advantage in aerial and industrial photography. Its actual and future possibilities in the radiologic field are investigated in this excellent monograph.

The authors, after a short historical note, present a thorough study of all the factors affecting the quality of an original roentgenogram and its reproduction on film or paper. They review the "dodging" principle, by which the enhancement of detail is obtained by shading zones of high contrast. Previously, this was accomplished by hand waving or with the use of the "unsharp masks" technique. Today, this is achieved by photoelectronic modulation.

Actually, there are two apparatus available for the electronic modulation, the LogEtron by Johnson and Craig (Washington) and the Electronic Photographic Printer by Cintel (London).

With the use of the LogEtron, each area of the original film is reproduced with an exposure proportional to its density. This objective method of dodging reveals details contained in the film by compression of contrasting shadows and highlights and is a means for obtaining a series of identical reproductions. Electronic dodging has done away with the occasional perfect print; it has brought about an automatic improvement in all roentgenograms which contain information not detectable by the usual methods of observation, and this makes it invaluable for diagnostic purposes.

The authors describe the working parts of the apparatus and explain the technique developed as a result of their experience. They mention its one inconvenience, the boundary enhancement effect; *i.e.*, a shading of light areas, whereby impurities of films or screens become more evident.

They discuss its many advantages in reproductions of soft tissue roentgenograms of the neck, high voltage studies of the thorax and mediastinum, roentgenograms of the heart and big vessels, placentograms and roentgenograms of the limbs. In all these and many others, the LogEtron brings out important details and makes them reproducible in printed form.

At the end, the original paper by Craig on the LogEtron entitled "A fully automatic servo-controlled scanning light source for printing" is reproduced in the English language.

This monograph is outstanding in its conciseness and clarity. The numerous reproductions and schematic drawings have bilingual legends and are most helpful in showing the possibilities of this apparatus.

The book is strongly recommended to radiologists, medical photographers and all physicians who need illustrative reproductions in their work. As the authors say, "the LogEtron will be of service only to those who like good radiography."

H. P. LÉVESQUE, M.D.

RÖNTGENDIAGNOSTIK DES MAGEN-DARMKANALS. By Prof. Dr. R. Prévôt, and Priv.-Doz. Dr. M. A. Lassrich. Cloth. Price, $28.30. Pp. 346, with 544 illustrations. Georg Thieme Verlag, Herdweg 63, Stuttgart, Germany, 1959. In the U.S.A. and Canada, Intercontinental Medical Book Corporation, New York 16, N. Y.

This is the revised and enlarged version of a 1948 text on gastrointestinal roentgenology originally published by Nölke (Hamburg). As a rule, when a book must be deprecated, a polite reviewer begins by stressing all such virtues of the opus or of its author as can reasonably be mustered; conversely, in the case of a valuable contribution, such as this, the shortcomings may be listed first.

A glance at the table of contents reveals an apparently adequate coverage of the subject with sections on the esophagus, stomach, duodenum, small intestine, colon, gallbladder, pancreas, and a catch-all chapter on the acute abdomen. One finds, however, that an unwarranted amount of space is devoted to intestinal tuberculosis, a topic which is today admittedly of historic or otherwise academic interest, since it was relatively infrequent (except in terminal patients) even at the time when Stierlin's (nonspecific) sign of cecal irritability was introduced. The text contains several other outdated items, such as chronic appendicitis and aerophagia. Inclusion of the latter condition is somewhat mitigated by the fact that it is considered here as a transient pediatric situation, without reference to similar findings in adults.

Esophageal perforations are fleetingly mentioned in connection with diverticula and with fistula formation, but there is no description of a "spontaneous" rupture of the esophagus (Boerhaave). This point should have been stressed. Also, on the preliminary roentgenogram of the abdomen, one ought to be familiar with the almost pathognomonic appearance of sigmoid volvulus. To be sure, this condition is perfunctorily noted in the book, but without acknowledging the existence of the "ace of spades" revealed by the unsuccessful attempt to perform a barium enema study. It is stated that myomata and other benign tumors are encountered in the gastrointestinal tract and that they undergo, at times, malignant transformation. The problem of carcinoma and "sarcoma" of the stomach is also briefly considered.

The literature cited at the end of the book, an estimated 1,200 references, is both extensive and polylingual. Maxwell Poppel's papers on postparotidic pancreatitis and on the mucous colon are quoted, as well as some other publications by American authors.

The best part of the book is its illustrations. Their sharpness, detail, and contrast approach perfection. The extra-heavy vellum brings out the artistic beauty of these harmonious roentgenograms with their delicate shades of black on white (reproduced as positive prints). The excellent index, with literal cross references, facilitates locating any topic. The text is pleasantly fluent and comparatively easy to read. Still, this is neither a reference work nor a didactic compendium; it is primarily an atlas of gastrointestinal pathology. Most of the captions can be deciphered with a dictionary; thus, even with the deficiencies mentioned above, the book constitutes a desirable addition to any specialized library.

E. R. N. Grigg, M.D.

Medical Radiographic Technic. Second edition. Prepared by Technical Service, X-Ray Department, General Electric Company, under the original editorial supervision of the late Glenn W. Files, revision by William L. Bloom, Jr., John L. Hollenbach, R. T., James A. Morgan, R.T., and John B. Thomas, R.T. Cloth. Price, $11.00. Pp. 386, with numerous illustrations. Charles C Thomas, Publisher, 301–327 East Lawrence Avenue, Springfield, Ill., 1959.

The second edition of this well-known text brings up to date the principles and techniques of modern diagnostic radiology. It is a small, handy, yet complete reference guide written by technicians for technicians, but the value to the radiologist is self-evident. As in the first edition, enough of the theory of physics and chemistry is included to permit this text to be used as a basis for study by x-ray technicians applying for a certificate of registration.

A new chapter on special procedures has been added to show the technique for 25 different contrast studies. Magnification techniques are also included. There are charts for body section roentgenography, and the chapter on high voltage roentgenography has been enlarged and illustrated. Positioning is again adequately covered, utilizing the mirrored image device. This second edition should be a welcome and useful replacement for the tattered and shopworn copies of the first edition.

Arch H. Hall, M.D.

BOOKS RECEIVED

Diagnosis and Treatment of Diseases of the Trachea and Bronchi. Publication No. 389, American Lecture Series. By Herman J. Moersch, M.D., and Howard A. Andersen, M.D., both from the Section of Medicine, Mayo Clinic and Mayo Foundation, Rochester, Minn. Cloth. Price, $4.25. Pp. 108, with 35 illustrations. Charles C Thomas, Publisher, 301–327 East Lawrence Ave., Springfield, Ill., 1960.

Collected Papers from The Radiumhemmet and The Radiopathology Institute of King Gustaf V's Jubilee Clinic. Volume VIII: 1, 1957–1958. Cloth. Pp. 542, with numerous illustrations. Karolinska Sjukhuset, Stockholm, Sweden, 1959.

ABSTRACTS OF RADIOLOGICAL LITERATURE

Department Editor: T. LEUCUTIA, M.D., Harper Hospital, Detroit 1, Michigan

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RADIATION THERAPY

Hughes, William F. Beta radiation sources, uses, and dangers in treatment of the eye. *J.A.M.A.*, Aug. 22, 1959, *170*, 2096–2101. (From: Department of Ophthalmology, University of Illinois College of Medicine, Chicago, Ill.)

Beta radiation from radium, radon and radium D-E has been used in the treatment of ocular conditions in the past. More recently, strontium 90 and yttrium 90 have also become available for this purpose. The early enthusiasm for treatment with a localized source of radiation with relatively superficial effects has been tempered by the appearance of secondary complications such as cataracts.

Certain information about the characteristics of each applicator is desirable: (1) the quality of the radioactive emanations (the amount of beta rays and gamma rays and the energy of the beta particles); (2) certification by the National Bureau of Standards of the quantitative output in rad surface output; and (3) experimental and clinical trials to corroborate the output.

Favorable results with beta radiation have been obtained in the treatment of corneal vascularization, limbal tumors, vernal catarrh, allergic (phlyctenular) keratitis, conjunctival papillomas and hemangiomas, and trichiasis. The general indications for beta radiation are the same as those for other forms of radiation such as the roentgen ray. Knowledge of dosimetry and of the differential sensitivity of the ocular tissues is extremely important, especially when radiation is given near the limbus. The minimal cataractogenic dose over the limbus with the strontium 90 applicator appears to be approximately 5,000 rads at the applicator surface. In general, beta radiation should be reserved for use in those ocular conditions in which it is superior to other methods of treatment or in which other methods have failed.—*Bernard Loitman, M.D.*

Dedick, Andrew P., Jr., and Whelan, Vincent M. Generalized skin reaction following deep x-ray therapy. *Radiology*, May, 1959, *72*, 751–753. (Address: A. P. Dedick, Jr., 67 E. Front St., Red Bank, N. J.)

Generalized skin reaction following deep roentgen-ray therapy is encountered rarely. Few cases have been reported but it is possible that numerous cases have gone unrecognized. A prodromal period, lasting from five days to six weeks and characterized by fever and malaise, follows completion of the irradiation and precedes the generalized skin eruption. The skin at the irradiated sites is not involved in the generalized reaction.

Three cases are reported by the authors. Each of these 3 patients received approximately the same amount of radiation over the same time interval and to the same area. All were treated with 200 kv. roentgen rays, half value layer 1.2 mm. Cu. Generalized morbilliform eruption, with severe itching, was present. Steroid therapy was used in 2 of these patients, with rapid control of symptoms.—*A. W. Sommer, M.D.*

Kaplan, Henry S. New horizons in radiotherapy of malignant disease. *J.A.M.A.*, Sept. 12, 1959, *171*, 133–138. (Address: Stanford University Medical Center, Palo Alto, Calif.)

Radiotherapy today is in dynamic flux with significant advances being made on several fronts. First in evidence of this progress at the clinical level is an encouraging spirit of cooperation between surgeons and radiotherapists making joint consultation in the treatment of potentially curable patients. Selection of optimal treatment plans depends upon the availability of proper statistical evaluation of end results achieved by different treatment methods. Such standards as the League of Nations classification for carcinoma of the cervix are needed for other primary sites to aid in comparing treatment methods. Sufficient case material to answer some of the clinical questions raised in the treatment of cancer is found only in large, fully-staffed cancer centers where there is centralization of radiotherapeutic care.

Advances in radiologic physics have now provided us with a variety of new, high energy radiation sources and more precise methods of dosimetry. Currently available sources of high energy radiation include: (1) van de Graaff generators—peak energy 2 mev.; (2) resonance transformer machines—peak energy 2 mev.; (3) cobalt 60 teletherapy machines—energy equivalent to 3 mev. roentgen ray; (4) linear accelerators—4 to 6 mev. roentgen rays; and (5) betatrons—roentgen rays with peak energies of 15 to 30 mev. All of these machines have significant advantages over the conventional 200 kv. machines: skin damages are minimized; the beam edge of supervoltage radiation remains sharp as it penetrates deep tissue; greater depth dose enables achievement of tumoricidal doses even in obese patients; and supervoltage radiation has little or no differential absorption in bone. Still other physical advantages are offered by high energy particulate radiations, notably cyclotron deuterons and protons, and high energy electrons generated by betatrons or linear accelerators.

Careful plotting of the precise dose distribution becomes necessary in supervoltage therapy. Skin reactions, which served as some sort of clinical guide in 200 kv. therapy, do not appear with supervoltage radiation. "Hot spots" must be determined when multiple fields are used. Likewise, "cold spots," where tumor cells persist, must be detected. The services of a trained radiation physicist become invaluable.

Analysis of end results and comparison of survival figures between conventional and supervoltage treatment methods require sufficiently long follow-up studies. Early data on these results point to a superiority of supervoltage irradiation over deep roentgen-ray therapy in eradicating cancer.

Fundamental studies are underway in the field of cellular biology which offer great promise for the future. The basic mechanism of cellular death by radiation is unknown. Chromosomal damage may lead to abnormal mitosis or inability to initiate mitosis. Nucleolus injury may be a factor in the mechanism of mitotic failure and cell death. Damage to the cellular protein (DNA) synthesis mechanism may play some role in the cell's inability to divide. Protein synthesis inhibitors such as chloramphenicol can prevent repair of radiation-induced chromosome breaks and so increase the yield of abnormal chromosomes produced by a given amount of radiation. Culture of human cells is now possible and may provide indices of radiosensitivity in different classes of cells and tumors *in vitro*. Estimates of tumoricidal doses may be possible on the basis of these tests.

Blood supply and oxygen tension are important factors in the radiosensitivity of many biologic systems and tumor tissues. Studies are under way to make use of this fact, that is, to eliminate the differences in oxygenation between normal and neoplastic tissues. Pretreatment with chemical sensitizers is also receiving attention in several laboratories in an effort to learn what substances enhance the radiosensitivity in various types of neoplasms. All these advances should eventually be reflected in substantially improved end results.—*Bernard Loitman, M.D.*

BACHMAN, ARNOLD L., and MACKEN, KEVIN. Pleural effusions following supervoltage radiation for breast carcinoma. *Radiology*, May, 1959, *72*, 699–709. (Address: A. L. Bachman, Francis Delafield Hospital, New York 32, N. Y.)

In the years prior to supervoltage therapy, the development of a pleural effusion in a patient previously treated for carcinoma of the breast strongly indicated metastatic involvement of the pleura. This intrepretation was almost invariably correct since nonmalignant effusions were exceedingly rare when 200 to 250 kv. therapy was employed. As a result, the pleura was considered resistant to the dosages employed in conventional therapy, which rarely exceeded 3,000 to 3,500 r to the pleura. The recent use of ultra-high voltage therapy has permitted larger doses to be delivered to the pleura, pulmonary parenchyma, and mediastinum with a corresponding increase in radiation effects, including nonmalignant pleural effusions.

The authors report a series of 200 cases of carcinoma of the breast treated with 2 million volt radiotherapy, of which 11 cases (5 per cent) developed nonmalignant effusions, as evidenced by the subsequent course and clinical observation for periods up to four years. These radiation effusions represented a large group among the cases which developed effusions within twelve to eighteen months following treatment. In all cases therapy was directed to the axillary, supraclavicular, and internal mammary regions and to the involved breast (in inoperable cases) through tangential ports, which resulted in doses of 4,000 to 6,000 r to the anterior pleura.

The authors state that the most significant factors in differentiating nonmalignant from malignant effusions were the time of appearance following therapy and the concomitant presence of radiation pneumonitis. In the majority of the 11 postirradiation cases, the fluid was first observed between two and four months after treatment and not once after six months. In each case the fluid was accompanied by a radiation pneumonitis and in no case did the effusion precede the pneumonitis. The pneumonitis was generally located in the upper lobes, corresponding to the axillary and supraclavicular fields. The development of fluid in the opposite chest and the re-accumulation of fluid on the treated side indicated metastases.—*Edward B. Best, M.D.*

HURST, DAVID W. Radiation fibrosis of pericardium, with cardiac tamponade; case report with post-mortem studies and review of literature. *Canad. M. A. J.*, Sept. 1, 1959, *81*, 377–380. (From: Departments of Pathology, Queen's University and Kingston General Hospital, Kingston, Ontario, Canada.)

The author reports the case of a thirty-four year old woman who received two courses of roentgen irradiation seventeen months apart for carcinoma of the breasts. The total estimated dose to the anterior pericardium was 4,800 r. Twenty-two months after the second course there was a rapid onset of dyspnea, nonproductive cough and hoarseness, along with swelling of the abdomen and general edema. Death ensued nine days after admission to the hospital. Operation and post mortem findings showed pericardial thickening with effusion and cardiac tamponade. The pathologic changes in the heart, lungs and pericardium on the basis of microcopic findings were thought to be the result of irradiation.

The author points out that there must be considerable variation in individual tolerance of the pericardium to irradiation. In the reported case the damage to the myocardium may well have been an additional factor in the cardiac failure.—*Arthur E. Childe, M.D.*

FRITZ, HEINRICH. Das Erscheinungsbild der Radionekrose im Scham- und Sitzbein. (The

appearance of radiation necrosis in the pubic bone and ischium.) *Strahlentherapie*, June–July, 1959, *109*, 510–522. (From: Strahlenklinik der Medizinischen Akademie Dresden "Carl Gustav Carus," Dresden, Germany.)

Of 2,800 female patients with pelvic carcinomas treated with roentgen and, partly, with radium rays, 53 showed skeletal changes in the pelvis. In addition, pelvic changes were demonstrated in 2 treated males. Almost all of the patients with skeletal changes were older than fifty-five years. Of the 53 women, 24 had unilateral and 4 had bilateral femoral neck fractures. Of these 28 patients, 17 also showed ipsilateral pubic or ischial damage. Of all patients observed, 29 (55 per cent) had pubic or ischial changes; 8 of them were fractures.

The changes consisted of sclerosis or patches of decreased density in the pubic bone or ischium, some of which healed spontaneously. In the patients who develop fractures, no active treatment is necessary. Severe pain is the only indication for bed rest; otherwise, light work is permissible.

Therapy with cobalt 60 probably will decrease skeletal damage incidental to treatment of pelvic carcinomas.—*Henry G. Moehring, M.D.*

Sebek, Alois, Rubes, Rudolf, and Venclík, Hynek. Über Spätveränderungen am Rückenmark nach der wegen eines Larynxkarzinoms vorgenommenen Strahlentherapie. (Late changes in the spinal cord after radiation therapy of a laryngeal carcinoma.) *Strahlentherapie*, April, 1959, *108*, 567–573. (From: Pathologisch-anatomische Abt., Onkologische Abt. und Otolaryngologische Abt. des Kreisinstituts für Volksgesundheit, České Budějovice, Czechoslovakia.)

In February, 1953, a forty-eight year old male with a negative Wassermann reaction, was treated for an undifferentiated carcinoma of the left half of the larynx and the root of the epiglottis with some spread into the subglottic region. A total laryngectomy was followed after three weeks by thirty-seven days of radiation therapy. Three 6×8 cm. fields (two anterolateral and one dorsal) received 4,389 r each (focal skin distance 50 cm., 1 mm. Cu and 1 mm. Al filters, 12 ma., 180 kv., half value layer of 1.3 mm. Cu). The tumor dose was 5,837 r and the region of the cervical spinal cord received 3,072 r.

In June of 1955, neurologic signs and symptoms appeared: disturbances of urination, pain and burning in the lower extremities, and unsteady gait. These progressed until all extremities were paralyzed by September, 1955. The patient died of pulmonary embolism in October, 1955, four months after the onset of neurologic signs and symptoms, and two and one-half years after the radiation therapy.

The histologic findings in the cervical spinal cord consisted of fibrinoid necrosis of the cord and extensive thickening and hyalinization of the media and, to a somewhat lesser degree, of the intima of the vessels. Similar vascular changes were present in the regional soft tissues which had been in the radiation fields.

These changes are ascribed to irradiation. Eighteen other patients who had essentially the same treatment for similar carcinomas during this time developed no neurologic abnormalities, so the authors assume that the reported patient had vessels with unusual individual susceptibility to radiation damage.—*Henry G. Moehring, M.D.*

RADIOISOTOPES

Levy, Richard P., Caughey, Patricia, and Turell, David. Daily variations in the thyroidal uptake of I^{131} in human subjects. *J. Clin. Endocrinol. & Metabol.*, June, 1959, *19*, 632–637. (From: Departments of Medicine, Western Reserve University, University Hospitals and Veterans Administration Hospital, Cleveland, Ohio.)

Forty-nine subjects were studied on successive days in order to more completely evaluate the frequency, magnitude and clinical significance of daily variations in the thyroidal I^{131} uptake studies which have previously been reported. All patients were clinically euthyroid. Normal serum protein bound iodine levels (3.5–7.4 μg. per 100 ml.) were found in each. Appropriate methods were used to measure the I^{131} activity over the neck and thigh at three and twenty-four hours after the ingestion of each tracer dose. All the twenty-four hour urine specimens were examined for creatinine and I^{127} in 32 patients.

The data obtained showed no significant differences between day one and day two regarding the mean thyroidal uptake and its standard deviation. Of the 29 patients, whose uptakes were below 30 per cent on both days, only 1 had day to day variations exceeding 7 per cent; however, of the 20 patients with uptakes over 30 per cent, 6 showed variations of 9 per cent or more. Two of the 3 patients with nontoxic goiters and 1 with previous thyrotoxicosis were among these last 6.

A wide range of iodine excretion was found (96 μg. to 1,190 μg. one day). When the daily excretion of I^{127} was less than 500 μg., there was no demonstrable relationship between the I^{127} excretion and I^{131} uptake; however, no patient with I^{127} excretion greater than 500 μg. had an I^{131} uptake greater than 20 per cent nor did the uptakes show a day to day variance in excess of 3 per cent.

The results indicate that there is sufficient variation in day to day uptake in about 10 per cent of pa-

tients to be of clinical significance. Those patients with known thyroid disorders seem more prone to exhibit variations. The importance of obtaining protein bound iodine determinations as well as I^{131} uptakes in determining thyroid reserve is stressed. The results of the serum protein bound iodine determinations made on successive days in 22 of the patients showed variations of 1.0 μg. or less (no statistical difference), indicating that this measure of thyroid function is relatively constant over a short period. One μg. represents, however, a variation of 15 per cent to 25 per cent in this group.—*Daniel L. Rousseau, M.D.*

MILLER, WADE N., and JACOBSON, LILLIAN E. Alterations of thyroid function in severe heart disease, as measured by I^{131} techniques. *J. Clin. Endocrinol. & Metabol.*, Aug., 1959, *19*, 949–952. (From: Radioisotope Department, Presbyterian Hospital in Newark, Newark, N. J.)

It is known that the thyroidal clearance rate for I^{131} is lower in cardiac patients than in normal euthyroid subjects. On further study, the authors found that 18 patients with severe heart disease showed a decrease in the 24 and 72 hour PBI^{131} and a decrease in the 24 hour I^{131} conversion ratio. Twenty-four hour I^{131} salivary activity studies showed an increase in radioiodine accumulation in the saliva compartment. Twenty-four and 72 hour radioiodine uptakes remained within the authors' range for the euthyroid state.

From their data the authors conclude that the decrease in PBI^{131} and the conversion ratio in the presence of heart disease indicates an impairment of thyroid hormone synthesis, the origin of which is still unknown.—*Frederick J. Bonte, M.D.*

JOINER, C. L. Rate of clearance of insulin labelled with ^{131}I from the subcutaneous tissues in normal and diabetic subjects. *Lancet*, May 9, 1959, *1*, 964–967. (From: Diabetic Clinic and Radioisotopes Laboratory, Guy's Hospital, London, S. E. 1, England.)

The effects of site of injection, variation in volume and concentration, exercise, hyaluronidase injection and lipodystrophy on the rate of absorption of insulin were studied in male and female control and diabetic patients utilizing I^{131} labelled insulin. The studies were made on 59 male and 38 female control subjects and on 24 male and 17 female diabetic patients.

A small volume (0.2 ml.) of crystalline insulin labelled with 10 μc I^{131} was injected subcutaneously and counts were made using a Geiger tube at five minute intervals until the radioactivity was reduced to one half of the original level (half period).

In males, the arm, leg and abdomen sites of injection showed half period clearance rates of 67 ± 11 minutes, 123 ± 18 minutes and 76 ± 20 minutes respectively. The female studies showed values of 55 ± 7, 99 ± 12 and 76 ± 20 minutes respectively. The insulin was cleared exponentially from the selected sites. The half period was not significantly influenced by variations in volume or concentration or by exercise. Hyaluronidase, however, produced a significant increase in the absorption rate.

The pilot study on the 41 diabetic patients was made using the leg injection site. Delayed clearance was found in 6 of 24 males and in 9 of 17 females. The main difference in the normal and delayed clearance patients was the duration of the disease; the normal groups had the disease for approximately one-half the time of its duration in the delayed groups. Clearance time also seemed to increase with age.

The above findings suggest that the repeated injections damage the subcutaneous tissues resulting in subsequent delayed clearance. It is especially interesting to note that 6 patients with delayed clearance of insulin from the leg showed normal clearance from the arm injection site. The possibility of association between lipodystrophy and delayed clearance is indicated.

The author concludes that: (1) if rapid subcutaneous absorption is indicated, the arm is the best site of injection; (2) more stress should be placed on instructing the diabetic patient to vary the site of injection; and (3) in some cases the use of hyaluronidase may facilitate absorption of insulin.—*Daniel L. Rousseau, M.D.*

BAKAY, L., BALLANTINE, H. T., JR., and BELL, E. P^{32} uptake by normal and ultrasonically irradiated brain tissue from cerebrospinal fluid. *A.M.A. Arch. Neurol.*, July, 1959, *1*, 59–67. (From: Department of Neurosurgery, Massachusetts General Hospital, Boston, Mass.)

In previous works the authors have shown increased deposition of intravenously administered inorganic P^{32} in lesions produced in the brains of cats by focused ultrasound. The increase was explained as being caused by an alteration of the blood-brain barrier, and not as the result of hemorrhage into the lesion, since ultrasound brain lesions are not hemorrhagic.

To investigate this phenomenon further, P^{32} was injected into the cisterna magna of cats from one hour to three days after the production of lesions by ultrasonic irradiation. Results were quite variable, and seemed to depend upon whether there was direct contact between the lesion and the cerebrospinal fluid. To some extent, poor mixing of the inorganic phosphate with the cerebrospinal fluid appeared to be responsible for inconclusive results which seemed to indicate no increased uptake of P^{32} in the experimental lesions.

When P^{32} as inorganic phosphate was directly ap-

plied to the cut surface of a cat brain at the level of an experimental ultrasound lesion, once again there was no specific uptake of the tracer by the damaged tissue. Counting and autoradiographic detection methods were employed.

The inability of the tissue of the experimental lesions to take up P^{32} applied in direct contact suggests that increased uptake cannot be caused by cellular metabolism alone. On the basis of this experiment the authors conclude that impairment of the blood-brain barrier is principally responsible for the deposition of P^{32} in the tissue of experimental ultrasound lesions.—*Frederick J. Bonte, M.D.*

Werner, Sidney C., Becker, David, V., and Row, Vas V. Distribution of serum radioiodinated compounds in euthyroid and hyperthyroid patients following hypophysectomy. *J. Clin. Endocrinol. & Metabol.*, Aug., 1959, 953–957. (From: Department of Medicine, Columbia University College of Physicians and Surgeons, Department of Medicine, Cornell University School of Medicine and the New York Hospital, New York, N. Y.)

Following hypophysectomy there was a change in the chromatographic distribution of radioiodinated compounds in the serum after a tracer dose of I^{131}, in 6 euthyroid patients undergoing the operation because of far-advanced cancer. Before surgery virtually all of the administered tracer could be found in the thyronine compartment at three days, the result of the normal mechanism of hormone formation. After hypophysectomy tracer iodine was found almost wholly in the iodide fraction due to the secondary hypothyroidism produced by the surgical procedure.

These results are compared with values obtained in the cases of 2 patients with Graves' disease and 2 euthyroid patients exhibiting evidence of ophthalmopathy, all of whom were brought to hypophysectomy. In all 4 of these cases the major portion of a tracer dose of I^{131} could be recovered in three days in the serum thyronine fraction after surgery as well as before.

The authors speculate on various reasons for the apparent ineffectiveness of hypophysectomy in controlling Graves' disease which is active or in remission. One immediate possibility was that extirpation of the pituitary was incomplete in the Graves' group, but hypopituitarism developed in all patients in this series. The results of this study would, therefore, tend to suggest that the thyroid gland of Graves' disease is no longer under the influence of the TSH regulatory mechanism and is indeed autonomous, as some have suggested.—*Frederick J. Bonte, M.D.*

Molinatti, G. M., Camanni, F., and Tedeschi, M. Implantation of the pituitary with yttrium 90 in a case of Cushing's syndrome. *J. Clin. Endocrinol. & Metabol.*, Sept., 1959, *19*, 1144–1150. (From: Medical Clinic and Department of Endocrine-Surgery, University of Turin, Turin, Italy.)

Cushing's syndrome has been treated by hypophysectomy, electrocoagulation of the pituitary, section of its stalk, and implantation of the pituitary with radon seeds or colloidal gold.

Promising results in the treatment of patients with advanced breast carcinoma and malignant exophthalmos by implantation of the pituitary with yttrium 90 induced the authors to employ this technique in the treatment of Cushing's syndrome in a twenty-seven year old man. One pellet of yttrium 90 (5.4 mc) was implanted in the pituitary and eight months later complete clinical regression had been obtained. Hormonal determinations indicated relative adrenal insufficiency but the thyroidal and gonadal functions were normal.

The authors conclude that it is possible to correct hypersecretion of one pituitary hormone without inducing hypopituitarism on the hypothesis that pathologically hyperactive cells are more radiosensitive than normal cells.—*Bernard Loitman, M.D.*

Frey, E., and Cocchi, U. Die percutane Hypophysenspickung mit Radiogoldseeds beim metastasierenden Mamma- und Prostatakarzinom. (Percutaneous implantation of the hypophysis with radiogold seeds in metastasizing carcinoma of the breast and prostate.) *Schweiz. med. Wchnschr.*, June 20, 1959, *89*, 652–656. (From.: Röntgendiagnostisches Zentralinstitut und Radiotherapeutische Klinik und Poliklinik der Universität, Zürich, Switzerland.)

Generalized bone metastases from carcinoma of the breast or prostate are often very painful. Destruction of the hypophysis, even though it may not reverse the process, is said to have an analgesic effect. The procedure, following the technique established by Bauer, who has used it in over 380 instances, requires general anesthesia with tracheal intubation to avoid aspiration of blood. The approach is made through the inner canthus. The eyeball is retracted laterally, while the medial wall of the orbit is perforated with a trocar. A needle is inserted through this opening at an angle of about 8° to the midsagittal plane. The needle is advanced by tapping it gently with a plastic hammer. Progress is continuously checked by fluoroscopic examination with an image intensifier, which makes it unnecessary to turn the lights off in the operating room. When the needle tip (outside diameter 1.5 mm.) reaches the anterior chamber of the sella turcica, 4 radiogold seeds of 10 mc each are introduced at different depths by pushing them with mandrins of varying lengths. Total disintegration of 1 mc raises the site dose to 1,000 rad at 5 mm. distance. The 40 mc represent

potential necrosis of a sphere 10 mm. in diameter, which is sufficiently small to avoid the optic bodies.

In the series presented in this paper, there were 8 patients (7 females with carcinoma of the breast and 1 male with carcinoma of the prostate) with no operative mortality and only minor postoperative morbidity such as spontaneously receding orbital hematoma. No blindness or other ophthalmologic complications of consequence were observed. Pain was eliminated or considerably reduced in all patients. However, no definite bone sclerosis or recalcification could be demonstrated, although time of observation in these patients may have been too short. The primary lesion underwent shrinkage in some instances but hypophysectomy had no noticeable effect on liver or lung metastases. One of the patients expired in coma from liver failure due to multiple nodular metastases.

Two of the 4 patients who had died at the time of writing were autopsied; the sella turcica was found to contain a spheric area of necrosis 7 mm. in diameter in 1 case and 12 mm. in diameter in the other.—*E. R. N. Grigg, M.D.*

GURLING, K. J., BARON, D. N., and SMITH, E. J. RADLEY. Thyroid adenomas and thyrotoxicosis in patients with hypopituitarism following hypophysectomy. *J. Clin. Endocrinol. & Metabol.*, June, 1959, *19*, 717–725. (From: Royal Free Hospital and School of Medicine, London, England.)

While thyroid function is usually considered to be dependent upon the secretion of the thyroid stimulating hormone (TSH) by the anterior lobe of the pituitary gland, the authors submit detailed reports of two convincing exceptions and refer to several other reported exceptions to this theory.

The first patient, a fifty-two year old woman, underwent hypophysectomy in July, 1956, because of recurrent inoperable breast carcinoma. Her thyroid, adrenal and pancreatic function had been normal. Ten weeks following hypophysectomy, there was marked improvement in the cancerous condition, but diabetes insipidus, hypothyroidism, and impaired adrenal and gonadal function developed, indicating complete pituitary ablation. Eleven months following hypophysectomy, the patient exhibited thyrotoxicosis which was, at first, diagnosed as recurrent carcinoma complicated by an anxiety state. When no evidence of reactivation of the neoplasm was found and the thyrotoxic symptoms became more pronounced, the correct diagnosis was considered reluctantly and thyroid medication was terminated. Eight weeks later, the basal metabolism rate remained elevated to between +45 and +52, and serum cholesterol had fallen to 110 mg. per 100 ml. The radioactive iodine studies were elevated with the conversion ratio extremely high (96 per cent). There was no evidence of target-organ function except for the hyperthyroidism. A thyroid adenoma became palpable and this increased in size to 3×1.5 cm. during a two month period. The patient, when placed on antithyroid medication (carbimazole), improved in eight weeks and the control was maintained until August, 1958. The nodule disappeared in eight months.

The second patient, a forty-eight year old single female, underwent complete surgical hypophysectomy in October, 1957, because of osteolytic metastases originating from carcinoma of the right breast. While all evidence indicated that pituitary ablation was complete, she developed a 2×3 cm. adenoma of the right thyroid lobe in one month which increased in size to 3×5 cm. during the next month. One year later, this patient is active and well; the adenoma persists and the patient requires daily cortisone but not thyroid.

The authors believe it justifiable to conclude that in these 2 women, the thyroid adenomas functioned independently of the thyroid stimulating hormone secretion. The possibility that toxic adenoma (secondary thyrotoxicosis) is a separate entity from Graves' disease (primary thyrotoxicosis) is considered. Thyrotoxicosis, therefore, may not be necessarily a pituitary induced disorder.—*D. L. Rousseau, M.D.*

HEILMEYER, L., and KEIDERLING, W. Iron turn-over for haemoglobin synthesis and other purposes in health, infection and malignant disease. *German Med. Monthly*, Aug., 1959, *4*, 261–262; *Deutsche med. Wchnschr.*, 1959, *84*, 724. (Address: L. Heilmeyer, Medizinische Universitäts-Klinik, Hugstetter Strasse 55, Freiburg i. Breisgau, Germany.)

The radical changes in iron metabolism in patients with infection and malignant disease are well demonstrated by experimental observations in 3 relatively small groups of patients. The studies consisted of determination: (1) of the rate at which intravenously injected iron (radioactive) was removed from the blood, and (2) of the total amount of iron in the circulating plasma. The proportion of radioactive iron utilized in red blood cell formation was also determined. The absolute amount of iron used each twenty-four hours in hemoglobin synthesis was then calculated.

In a group of 7 healthy subjects, the plasma iron turnover averaged 34.3 mg. in twenty-four hours and the percentage utilization for hemoglobin synthesis was 81 per cent with the hemoglobin iron 27.9 mg. and nonhemoglobin iron 6.4 mg. In 17 patients with infections, the plasma iron turnover averaged 47.9 mg. and the percentage utilization was 76 per cent with the hemoglobin iron 37.4 mg. and nonhemoglobin iron 10.5 mg. In 9 patients with malignant disease, the plasma iron turnover averaged 89.6 mg. and the percentage utilization was 66 per cent with the

hemoglobin iron 60.8 mg. and the nonhemoglobin iron 28.8 mg. The results thus revealed that the iron uptake for hemoglobin synthesis is increased 35 per cent in cases of infection and 218 per cent in cases of malignant disease. The increased uptake compensates for the accelerated breakdown of the red blood cells, a finding which has been confirmed by other investigators.

Using the above data, the red blood cell life span was calculated as 100 days in healthy persons, 66 days in cases of infections and 41 days in cases of malignant disease. Most striking is the increase in nonhemoglobin iron turnover. This amounts to 64 per cent in infections and 450 per cent in malignant disease. This iron is utilized in the synthesis of myoglobin and heme enzymes and for turnover of storage iron. The storage iron, now a subject of further investigation, has important protective functions against bacterial toxins and products of tissue breakdown.—*Daniel L. Rousseau, M.D.*

Roche, Marcel. Elevated thyroidal I^{131} uptake in the absence of goiter in isolated Venezuelan Indians. *J. Clin. Endocrinol. & Metabol.*, Nov., 1959, *19*, 1440–1445. (From: Sección Medicina, Laboratorio de Fisiopatología, Instituto Venezolano de Investigaciones Cientificas, Caracas, Venezuela.)

This interesting study was carried out in a mountainous portion of Southeastern Venezuela along a tributary of the Orinoco River. One hundred and ten Indians belonging to two different tribes were examined and the thyroid gland was thought to be enlarged in only 2 instances. In 1 additional case, a girl of twelve, the thyroid was visibly enlarged and contained a solitary nodule in its left lobe. Twenty-four hour I^{131} uptake studies were performed on 53 of the Indians, and the average uptake was 70.8 per cent. Neither accumulation curves nor clearance rate studies were done. These elevated uptakes, thought to represent thyroidal avidity as the result of dietary iodine deficiency, occurred in natives whose diet consisted of dried yucca, fish and, occasionally, wild animal meat.

As a measure of control, twenty-four hour uptake studies were done on 7 members of the expedition and were found to lie in the normal range. Included among these was 1 study, also in the normal range, performed on an Indian who was a member of one of the tribes being investigated, but who had lived in an urban area for the fifteen preceding years.

These results suggest to the author that high thyroidal avidity for iodine may exist in a general population without goiter, and that iodine lack can apparently be present without giving rise to endemic goiter. It is suggested further that iodine deficiency may be a necessary requisite for, but not sufficient in itself to cause, endemic goiter.—*Frederick J. Bonte, M.D.*

Desaga, Hans. Zur Perchloratwirkung auf die Rückresorption von freiem Hormonjod durch die Schilddrüse; ein Beitrag zur beschleunigten Eliminierung von inkorporiertem J 131. (The effect of perchlorate on the reabsorption by the thyroid of free hormonal iodine; a contribution to the accelerated elimination of the bound I^{131}.) *Strahlentherapie*, May, 1959, *109*, 106–112. (From: Innere Abteilung des Luisenkrankenhauses Lindenfels/Odenwald, Germany.)

Perchlorate (administered by mouth in the form of a mixture of perchlorates with the trade name Irenat) blocks iodine uptake by the thyroid—not only ingested iodine, but also the iodine set free in the metabolic breakdown of thyroid hormone. In the author's experience, any dose over 1,200 mg. of perchlorate a day produced complete block of iodine uptake.

Administration of perchlorate thus is useful in washing radioactive iodine out of the thyroid, whether the absorbed iodine be a diagnostic or therapeutic dose. The effect can be enhanced by intermittent administration of perchlorate and iodides. Administration of perchlorates over a period of days does not result in undesirable secondary effects, *e.g.*, enlargement of the thyroid or stimulus to exophthalmus.—*Henry G. Moehring, M.D.*

Sevelius, Gunnar, and Johnson, Philip C. Blood flow determined by the use of radioiodinated serum albumin and an externally placed scintillator detector. *South. M. J.*, Sept., 1959, *52*, 1058–1061. (From: Radioisotope Service, Veterans Administration Hospital and Department of Medicine, University of Oklahoma School of Medicine, Oklahoma City, Okla.)

A method of determining blood flow through various organs and the coronary arteries is presented. The method is simple, not requiring catheterization, using an external scintillation counter only.

Using an adequate group of controls, studies were made on patients with known renal and coronary disease. Results are expressed in volume of flow per minute. Whether these figures are literally accurate is open to question. But the differences between the normal and abnormal are quite convincing. The matter of crystal size and collimation is critical and another potent source of error is the problem of organ localization.—*P. J. Cavanaugh, M.D.*

Gorten, Ralph J., and Stauffer, John C. A study of the techniques and sources of error in the clinical application of the external counting method of estimating cardiac output. *Am. J. M. Sc.*, Sept., 1959, *238*, 274–

279. (From: Radioisotope Division, Department of Medicine, University of Maryland School of Medicine, Baltimore, Md.)

The authors present a "simple" technique for determination of cardiac output by external counting. The purpose of the article is to help the interested beginner in setting up this technique. The possible sources of error and results to be expected are reviewed.

The authors suggest that this technique could be adopted by small radioisotope laboratories. One suspects, however, that the radiologist whose isotope work is confined to radioiodine uptake determinations would find this technique anything but simple.—*P. J. Cavanaugh, M.D.*

Reizenstein, P. G., and Nyberg, W. Intestinal absorption of liver-bound radiovitamin B_{12} in patients with pernicious anemia and in controls. *Lancet*, Sept. 5, 1959, *2*, 248–252. (From: Department of Internal Medicine and Gustaf V Research Institute, Karolinska Sjukhuset, Stockholm, Sweden; and Department of Internal Medicine, Central Hospital, Vasa, Finland.)

Ten patients with pernicious anemia and 17 control patients were fed weighed samples of calf or pig liver from animals that had received cobalt labeled vitamin B_{12}. Both groups also drank crystalline radiovitamin B_{12} in amounts comparable to that in the liver. All feces were collected from both groups from seven to eleven days after isotope administration.

Both controls and pernicious anemia patients apparently absorbed more of the liver B_{12}. The hematologic response after eating liver was greatest when most radioactivity was absorbed.

These studies also indicate that there may be forms of vitamin B_{12} which may be absorbed by patients with pernicious anemia in the absence of intrinsic factor.

Since the oral maintenance therapy of pernicious anemia patients with B_{12} intrinsic factor combinations is unsatisfactory, these studies suggest that oral administration of liver containing B_{12} in an absorbable form may merit more investigation in pernicious anemia therapy. There is also the possibility that some of the bound B_{12} as it occurs in food is more readily absorbed than crystalline vitamin B_{12}.—*P. J. Cavanaugh, M.D.*

Fillman, Eldon M., Hanson, Otto L., and Gilbert, Lael O. Radioisotopic study of effects of irrigating fluid in transurethral prostatectomy. *J.A.M.A.*, Nov. 14, 1959, *171*, 1488–1492. (Address: E. M. Fillman, 109 W. Ninth St., Topeka, Kan.)

Irrigating fluid absorption into the blood stream occurring during transurethral prostatectomy in a series of 11 cases was estimated by tagging the iso-osmotic irrigation solution with radioactive iodinated human serum albumin or with sodium chromate containing Cr^{51}. In all cases, the hydrostatic pressure employed was less than 75 cm. and operative times were one hour or less. In 9 cases, fluid absorption was less than 400 ml., while excessive absorption (1,780 ml.) occurred in 1 case in which the operative time was ninety minutes. The authors feel that irrigation fluid absorption can be reduced by the use of low hydrostatic pressures, a relatively superficial operative procedure which does not expose the deep sinuses, and a short operating time, as well as the use of an iso-osmotic irrigation fluid.

In another group of 8 patients, hemolysis due to irrigation fluid absorption was measured by tagging red blood cells with sodium radiochromate and measuring the total increase in radioactivity of the plasma during surgery and irrigation with sterile water. In no case was hemolysis measured at more than 44 ml., and in no patient were there ill effects due to hemolysis.

Blood loss was evaluated in another 6 cases by means of a Cr^{51}-tagged red blood cell technique, and was found to average less than 280 ml. in each case.

Although hemolysis does not appear to be an important complication during transurethral prostatectomy, even if sterile water is used as an irrigating fluid, the authors seem to feel that it is preferable to use an iso-osmotic irrigating solution.—*Frederick J. Bonte, M.D.*

Allegranza, A., Guidotti, G., Levi Setti, R., and Polvani, F. Autoradiographic detection in tissues of tubercle bacilli labelled with acetate-1-^{14}C. *Panminerva med.*, Sept., 1959, *1*, 178–180. (Address: A. Allegranza, Istituto Neurobiologico "A. Verga," Via Ippocrate 45, Milano, Italy.)

In the present study, tubercle bacilli (C_{37} Rv) were tagged by adding sodium acetate-1-C^{14} to the Sauton growth medium. Washed suspensions of labelled bacilli were injected intravenously into pregnant albino rats. The animals were sacrificed after two hundred and fifty minutes, and lungs, placenta and fetus were fixed, embedded and prepared for radioautography by coating with Ilford G5 photographic emulsion to a thickness of about 50 μ. With this technique, good radioautographic localization of bacilli could be detected in capillaries of the maternal lung and in the marginal sinuses of the placenta; no tagged bacilli could be found within fetal tissues, in agreement with the known inability of tubercle bacilli to pass through the placental barrier.

Other results suggested that this tracer technique might also be of value in localizing various fractions of killed bacilli.—*Frederick J. Bonte, M.D.*

Graul, Emil Heinz, and Hundeshagen, Heinz. Messtechnischer und insbesondere autoradiographischer Nachweis Tritium-markierter organischer Substanzen, dargestellt am Beispiel des Arginins. (Quantitative and autoradiographic measurement of tritium-tagged organic substances, presented with arginine as an example.) *Strahlentherapie*, April, 1959, *108*, 524–530. (From: Abteilung für Strahlenbiologie und Isotopenforschung der Strahlenklinik der Universität Marburg, Marburg, Germany.)

Tritium is becoming more important in biochemical and medical research because it is cheaper than carbon 14 and it can be combined in various ways with various substances by relatively simple methods.

The authors describe, and illustrate with autoradiographs, some of their observations on tritium-tagged arginine.—*Henry G. Moehring, M.D.*

MISCELLANEOUS

Hamburger, J. *et al.* Transplantation d'un rein entre jumeaux non monozygotes aprés irradiation du receveur. (Transplantation of a kidney between heterozygous twins after irradiation of the recipient.) *Presse méd.*, 1959, *67*, 1771–1775. (From: Research Centers of the Claude-Bernard Ass'n., Paris, France.)

A sublethal dose of whole body radiation was administered to a thirty-seven year old male in an attempt to weaken the body's ability to make nephrotoxic antibodies, or to diminish the cellular interstitial invasion which is characteristic of the rejection of homotransplants.

The patient, suffering from chronic kidney disease with impending failure, was given 260 rad from a cobalt^{60} source; six days later 200 rad was given and then the kidney of a heterozygous twin was transplanted. In the interim the patient had been maintained in an aseptic environment. The kidney functioned satisfactorily at once, but during the third postoperative week a critical stage occurred and was resolved; this may have been the crisis and cure of the immunologic disease.

Four months postoperatively the patient was in good condition with the transplanted kidney functioning normally.—*Frank A. Riebel, M.D.*

Carroll, Harold W., Spivack, Alfred P., and Brauer, Ralph W. Attempts to reproduce cirrhosis of the liver in rats after total-body x irradiation. *J. Nat. Cancer Inst.*, Oct., 1959, *23*, 669–673. (From: U. S. Naval Radiological Defense Laboratory, San Francisco, Calif.)

Animals that have survived radiation exposure and recovered to a degree that makes them superficially indistinguishable from controls have a reduced life expectancy and perhaps other physiologic and biochemical variations. Studies have been done attempting to reveal the latent injuries sustained by the animals. A previous report by White in 1955 showed that rats maintained on a 6 per cent protein (casein) diet developed gross and microscopic cirrhotic lesions of the liver after exposure to 450 to 500 r of roentgen irradiation. The authors attempted to reproduce White's results and to amplify them so as to assess the latent injury after apparent radiation recovery.

The authors' study showed that rats fed on a low protein (6 per cent casein) diet had fatty infiltration and varying degrees of fibrosis in the liver regardless of whole body irradiation, suggesting that the lesions are of dietary origin. The degree of fibrous proliferation seemed to depend on the age of the rat when placed on the diet. Cholene supplementations reduced the severity of the fibrous lesions.—*Charles W. Cooley, M.D.*

Maisin, J., Keusters, J., Guidetti, H., and Lambert, G. La réparation des radiodermites (étude expérimentale). (Healing of radiodermatitis [an experimental study].) *J. de radiol., d'électrol. et de méd. nucléaire*, Aug.–Sept., 1959, *40*, 451–460. (From: Institut du Cancer, Louvain, Belgium.)

Radiation dermatitis was produced in rats with heavy doses of superficial radiation and, under controlled conditions, various series of the animals were treated with vaseline, astreptine, powdered triglycerides, and combinations of these agents.

It was concluded that the weak healing action of vaseline is due only to a softening effect on the eschar. When saturated triglycerides (the chemistry of which is described) were added to vaseline, healing took place twice as rapidly as in the controls.—*Frank A. Riebel, M.D.*

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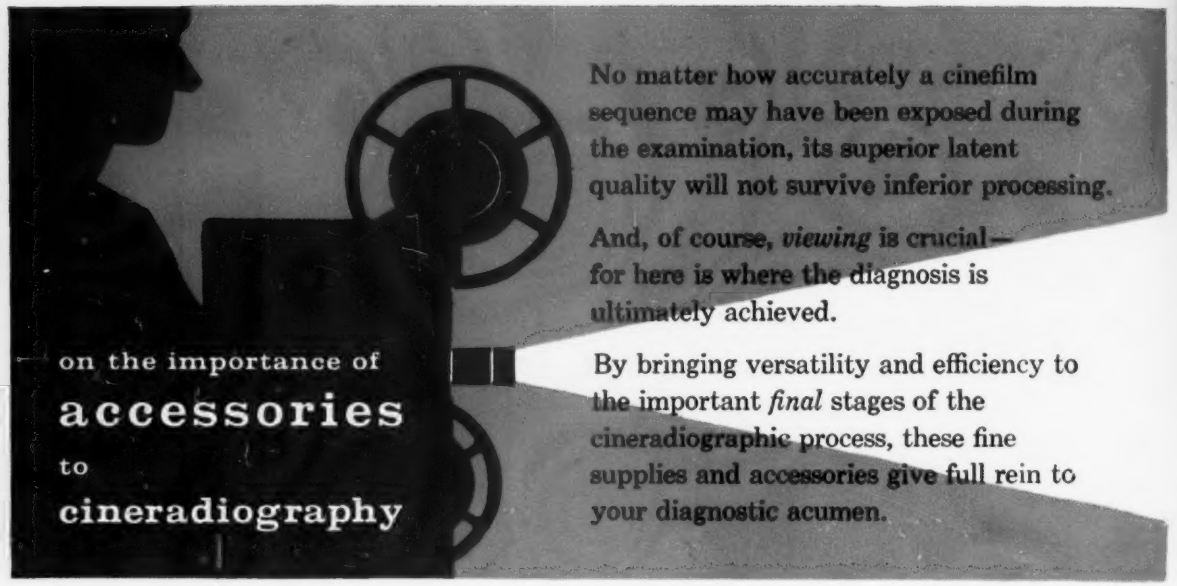

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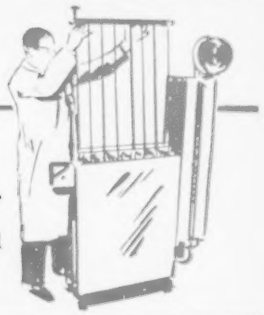

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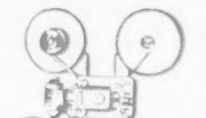

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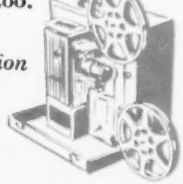

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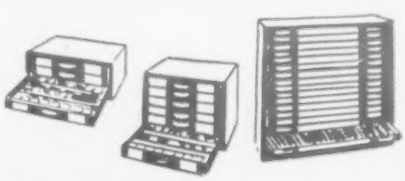

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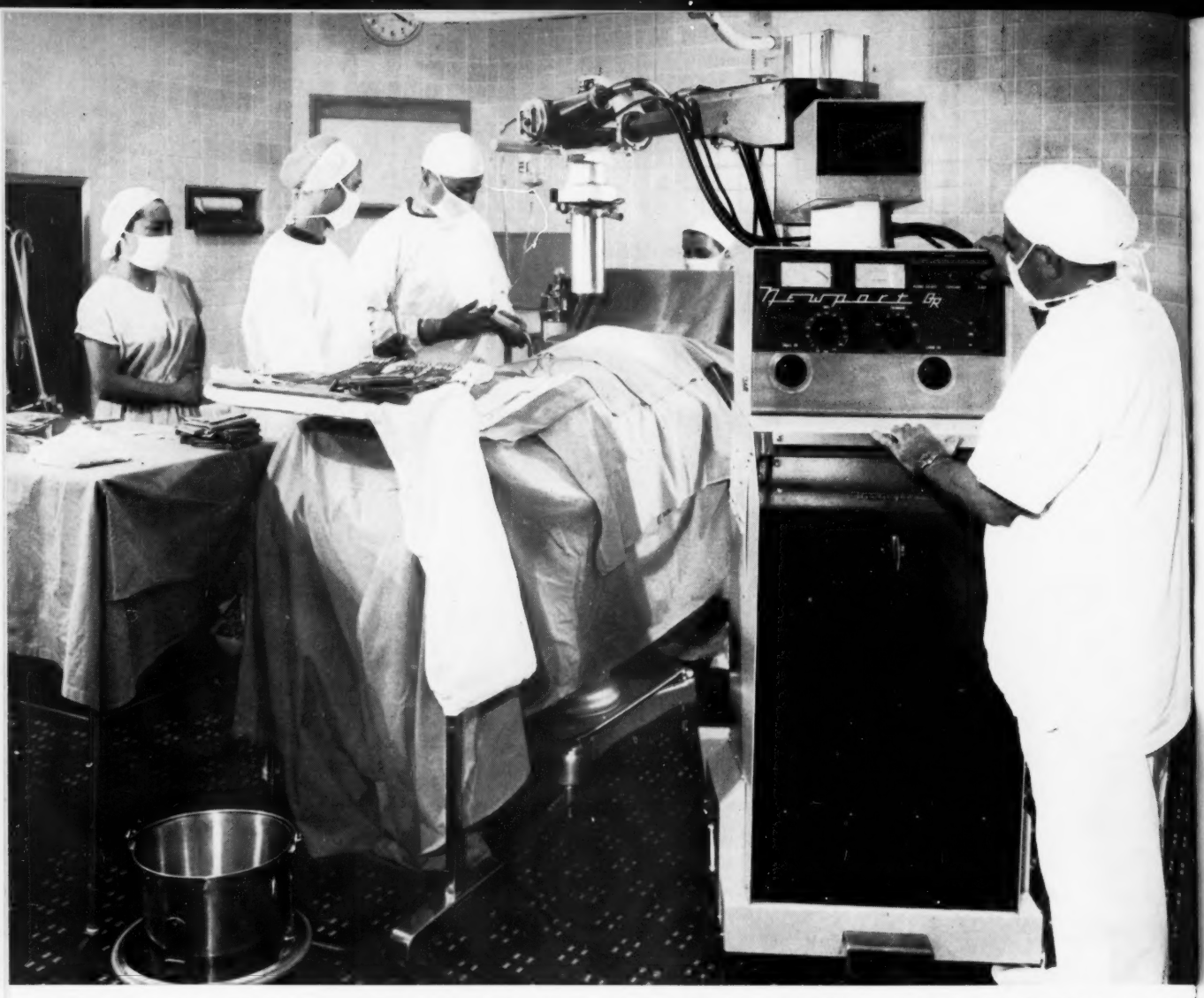

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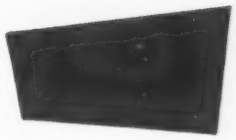

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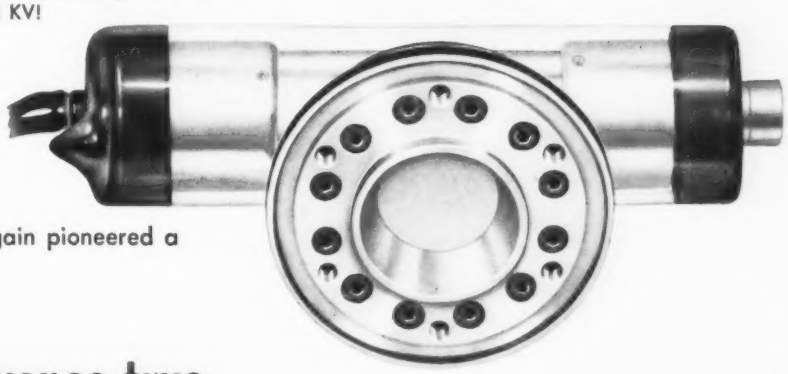

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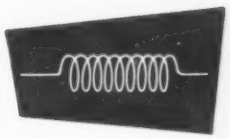

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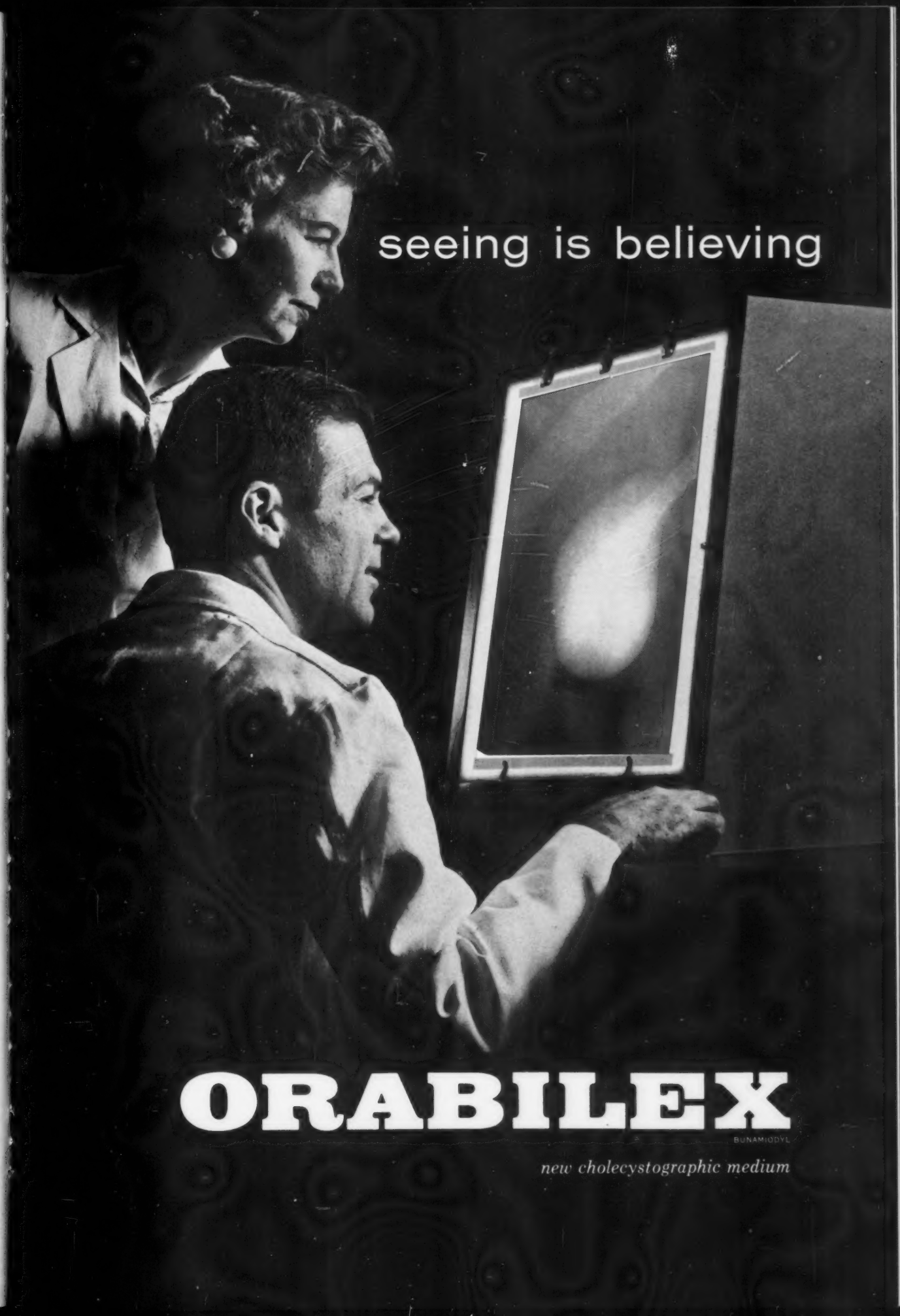
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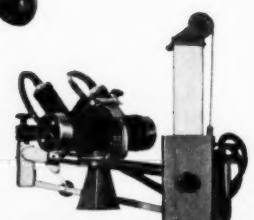

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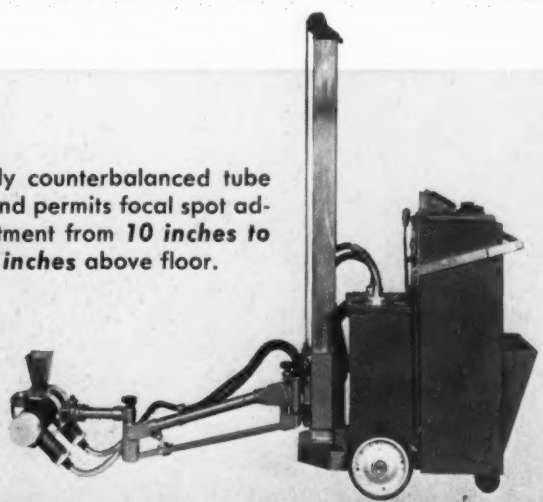

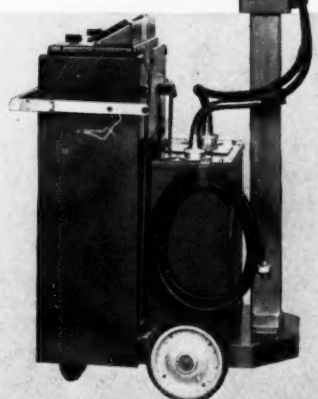

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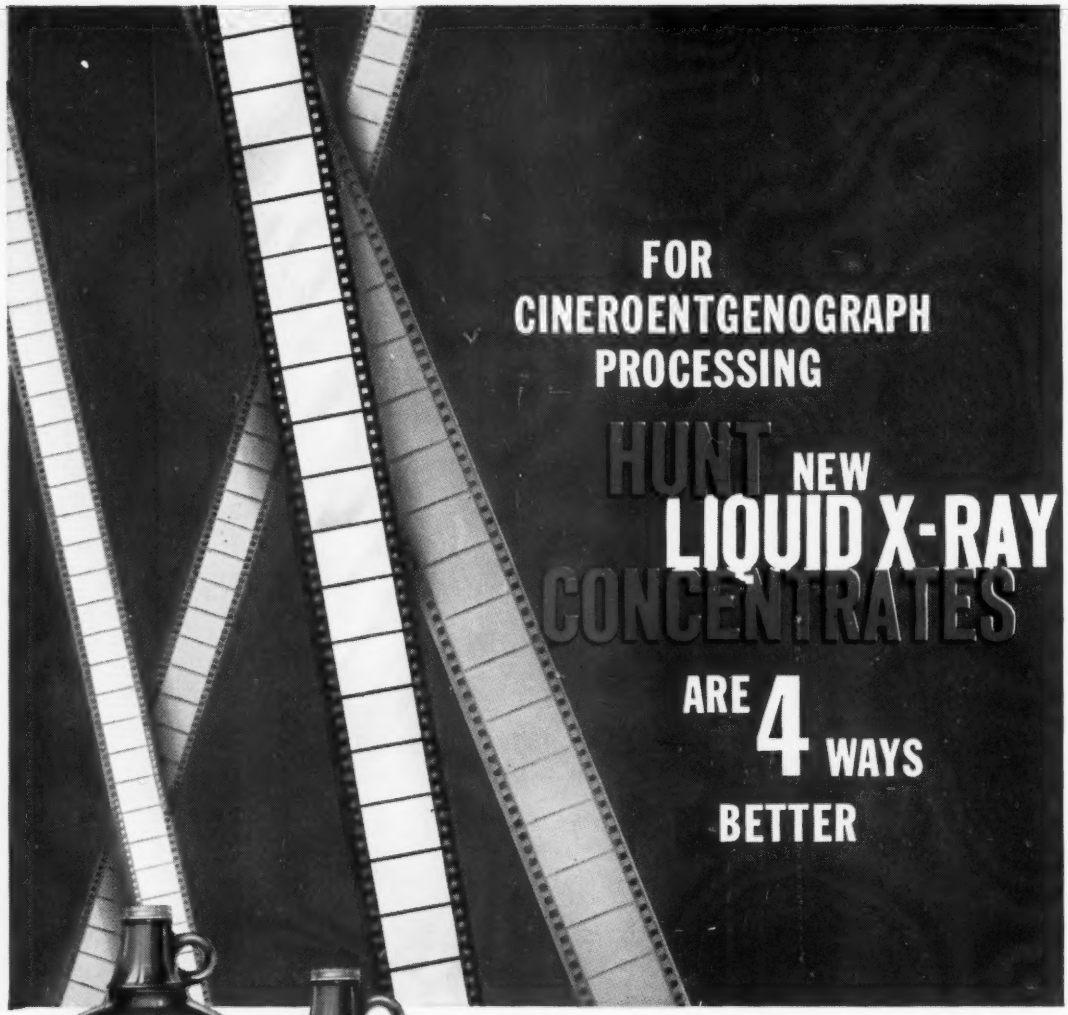

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HUNT FOR THE BEST IN MANUAL AND AUTOMATIC PROCESSING CHEMISTRY

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BRANCHES IN PRINCIPAL CITIES

In Canada: Philip A. Hunt Company (Canada) Ltd., 207 Queen's Quay West, Toronto

When it's HIGH KV

ILFORD Red Seal X-ray Film is Still Consistent in Contrast

Here is an extremely high-speed film, designed to complement the higher KV capacity of modern X-ray equipment. Ilford Red Seal provides the strong film contrast so necessary in the interpretation of high voltage radiographs.

"Washed out" radiographs are an unnecessary handicap to technician and radiologist alike. Red Seal is always consistent in contrast, in definition and in detail—even up to 150 KV!

This superior product is supplied in Ilford's exclusive package of 3 units of 25 films each, fully interleaved for maximum film protection.

ILFORD INC. 37 WEST 65th STREET, NEW YORK 23, N.Y.

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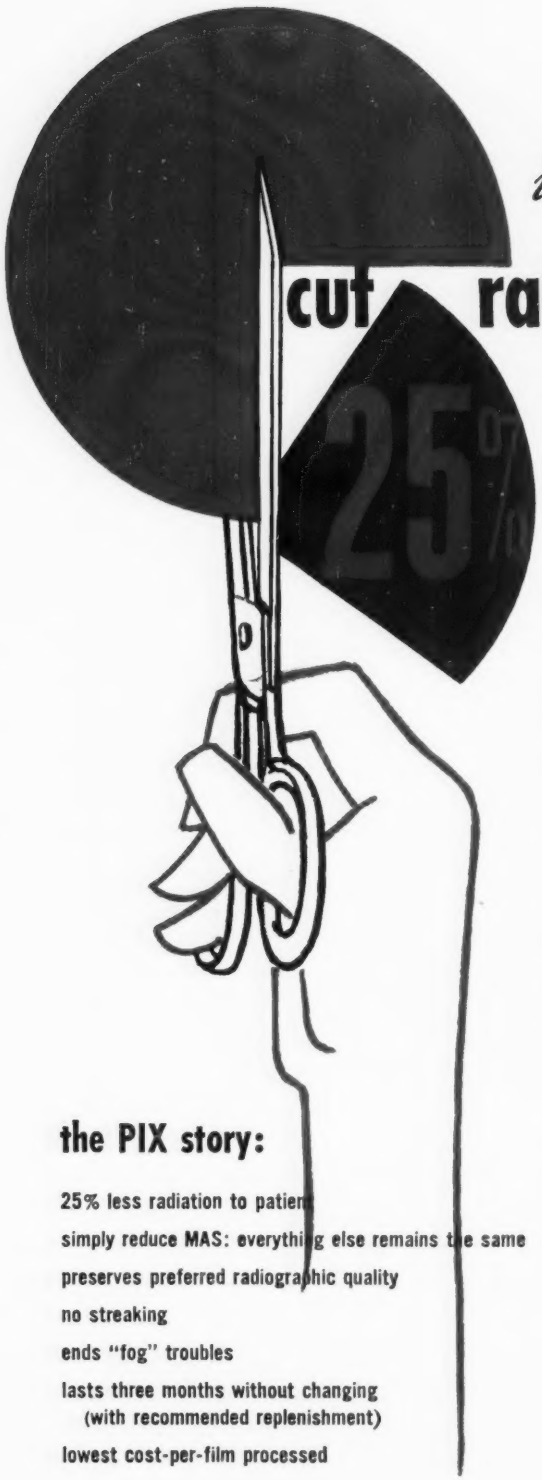


in radiography...

cut radiation dosage 25% by switching to PIX

and still get the same film-quality you're used to

It's over a year now since Picker startled the X-ray world by flatly making the above statement.

No ifs, ands, or buts to this firm promise then or now. No need for any, either: the on-the-job experience of thousands of users over the past year is proof positive of its validity.

If you're concerned with Minimal Dosage Radiography (and who isn't these days) the use of PIX is a dependable path to it. A call to your local Picker office can get you started right now. Or, if you prefer, write us. Picker X-Ray Corporation, 25 South Broadway, White Plains, New York.

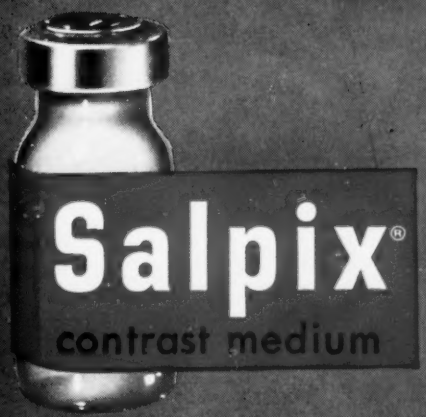
the PIX story:

- 25% less radiation to patient
- simply reduce MAS: everything else remains the same
- preserves preferred radiographic quality
- no streaking
- ends "fog" troubles
- lasts three months without changing (with recommended replenishment)
- lowest cost-per-film processed

new PICKER processing solutions for MDR minimal dosage radiography

PICKER X-RAY CORPORATION
25 South Broadway, White Plains, N. Y.

diagnosis
without
delay



in hysterosalpingography
for detecting uterine
and tubal abnormalities

Ortho Pharmaceutical Corporation
RARITAN, NEW JERSEY

Ortho

HIGH-ENERGY RADIATION

maxitron 2000

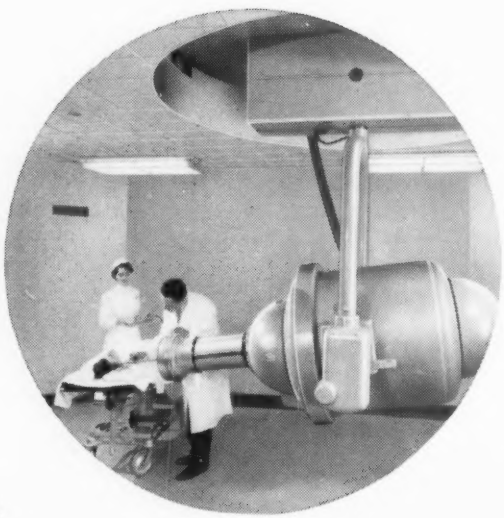
high dose rates at low cost per rad

2-MILLION VOLT X-RAY UNIT—the culmination of more than half a century's experience with radiation. Maxitron 2000 is the most powerful in the complete range of x-radiation therapy sources offered by General Electric.

With the Maxitron 2000, high-energy radiation is generated *electronically* . . . dose rate never decreases due to decay. No source—isotopic or otherwise—compares in maintenance savings. Records of medical centers show that not a single x-ray tube has failed in the entire decade since the first unit was installed! At dose rates provided by the Maxitron 2000, maintenance cost for delivery of 1000 rads to a tumor at 10-cm depth (100-cm square field) *has averaged only pennies!*

For full facts on any range of x-ray therapy equipment, see your G-E x-ray representative. Or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Room 1003F.

Maxitron is a G.E. registered trademark.

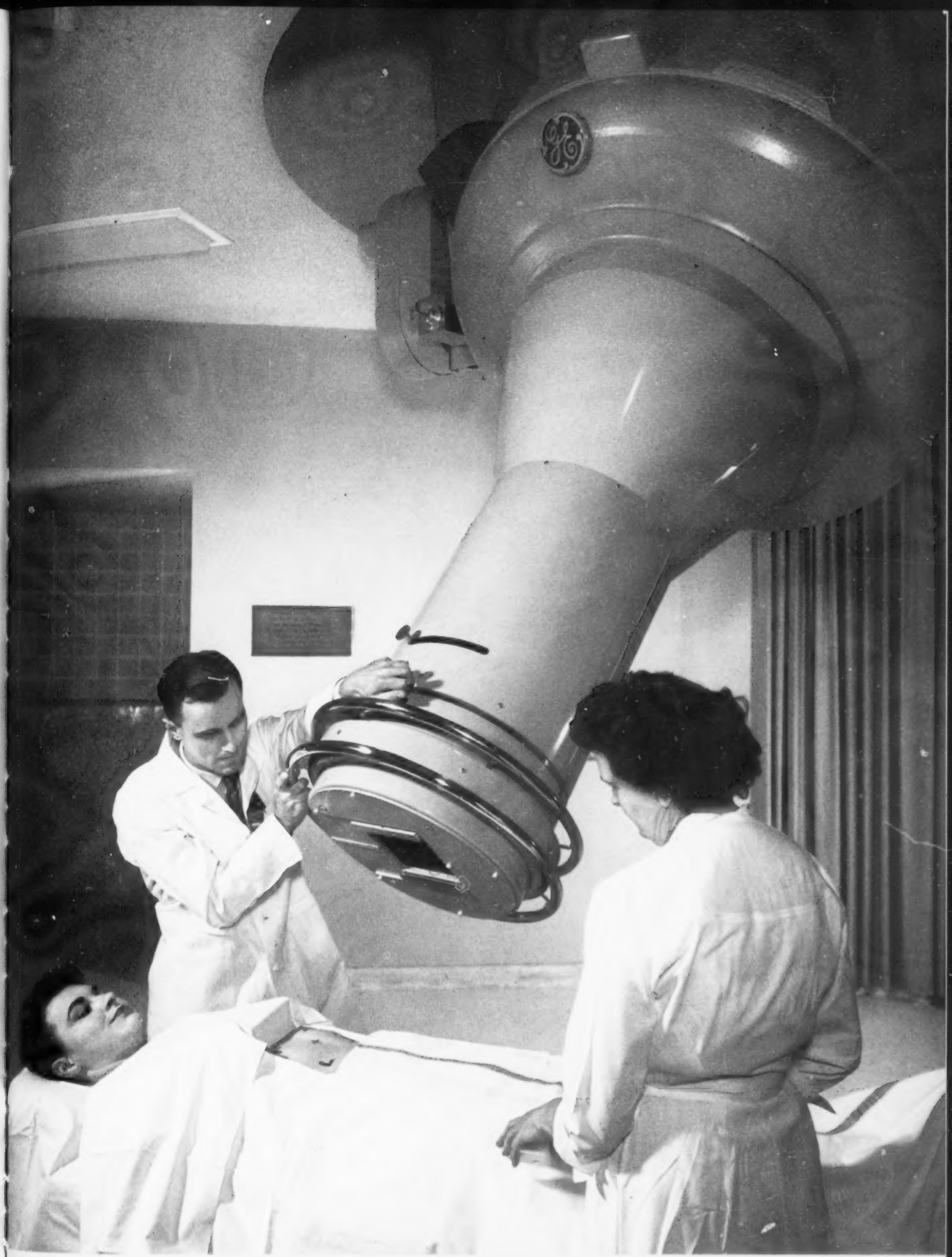


maxitron 1000

MILLION-VOLT X-RAY UNIT—Maxitron 1000 super-voltage therapy unit combines high-energy output, easy operation and duplication of dosage—thanks to *electronically generated* radiation. Here again General Electric quality has reduced maintenance per thousand rads to just *pennies.*

Progress Is Our Most Important Product

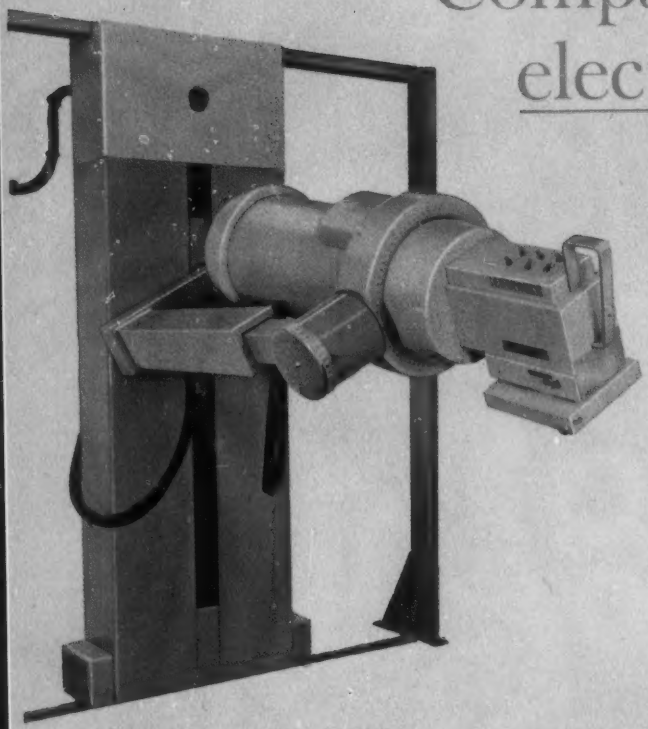
GENERAL ELECTRIC

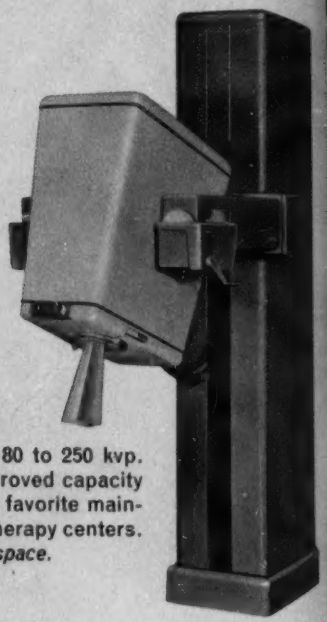


BAYLOR UNIVERSITY MEDICAL CENTER, DALLAS, TEXAS...
2-million volt G-E Maxitron 2000—one of the many now in service at key institutions across the continent. Pleasant surroundings encourage even apprehensive patients to rest easy during therapy.

DEEP, INTERMEDIATE AND SUPERFICIAL THERAPY

Compare these powerful electronic x-ray sources



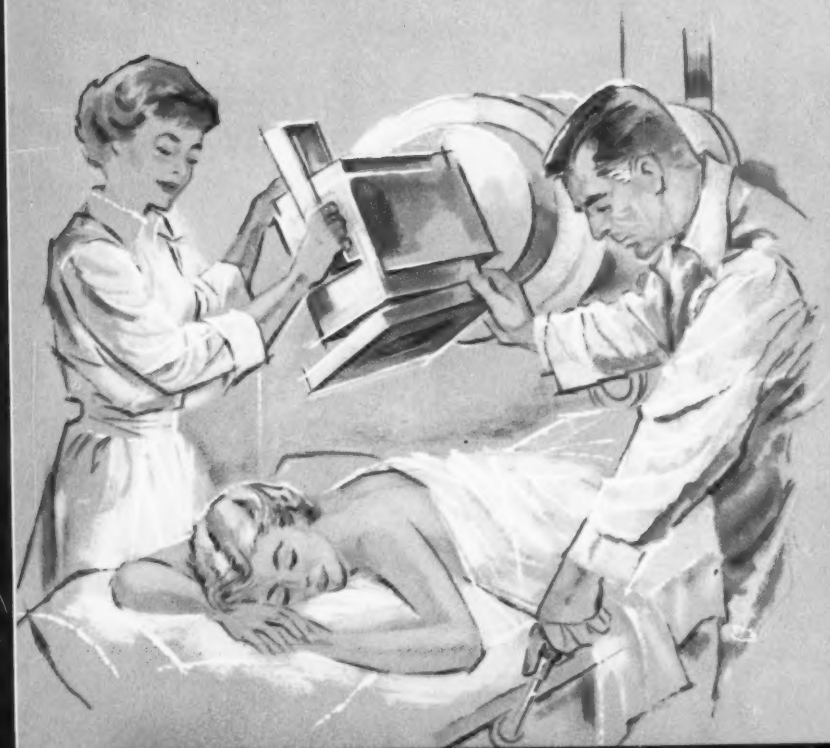


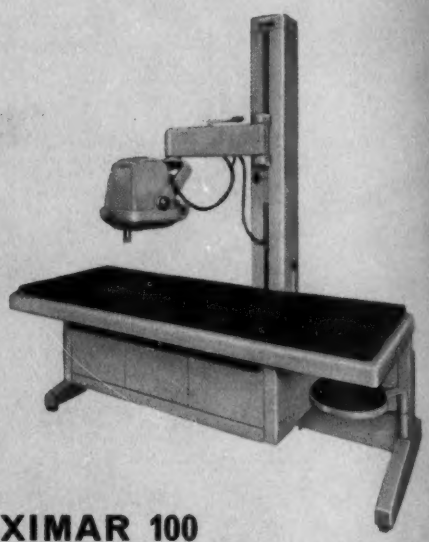
MAXIMAR 250-III

Deep to superficial therapy, at 80 to 250 kvp. Versatile performance and the proved capacity for continuous duty make this a favorite mainstay in many of today's busiest therapy centers. *Requires only 3¼ sq. ft. of floor space.*

MAXITRON 300

Deep to superficial technic . . . 100 to 300 kvp. Half-value layers ranging from 0.25 mm Al to 4 mm Cu. Dose rate and half-value layer can be dialed right from control console: correct filter positions itself, kvp and ma are preselected *automatically!*





MAXIMAR 100

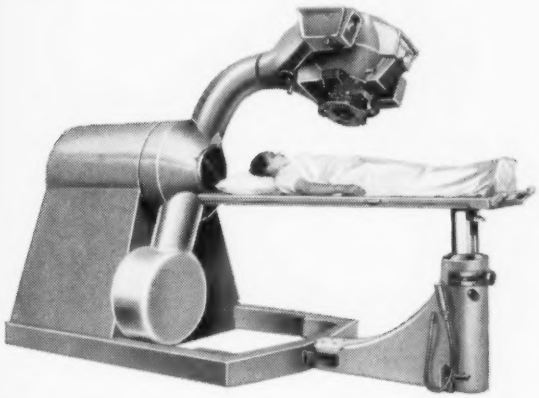
Superficial therapy . . . output from near grenz rays to that obtained at 100 kvp. *More than 5000-r per minute at 15-cm fsd* . . . up to 84% absorption in first 4 mm of tissue. Coverage at 30-cm fsd spans 18-cm circle; dose rate at edge of circle is within 80% of central axis dose rate.

Maximar and Maxitron are G.E. registered trademarks.
Litho in U.S.A.

ISOTOPE TELETHERAPY

Select from seven cobalt and caesium units

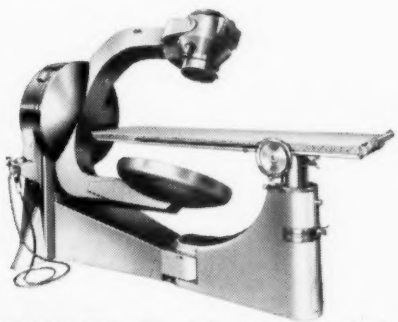
General Electric sells, installs *and services* a complete range of AECL isotope teletherapy equipment, capable of technics from conventional fixed-beam irradiation to complex rotational patterns. All have fail-safe shutters that close automatically in event of power failure.



THERATRON F (shown)—200 r/m/m maximum cobalt-60 source capacity. For fixed- and moving-beam teletherapy.

THERATRON B—165 r/m/m maximum cobalt-60 source capacity. Fixed- and moving-beam capabilities.

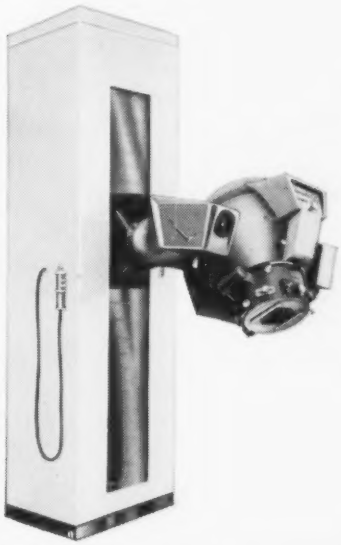
THERATRON C-II—50 r/m/m maximum cobalt-60 source capacity. For both fixed- and moving-beam technics.



THERATRON JR. (shown)—50 r/m/m maximum cobalt-60 source capacity. Fixed- and moving-beam teletherapy provisions.

Progress Is Our Most Important Product

GENERAL ELECTRIC



ELDORADO SUPER G (shown)—200 r/m/m maximum cobalt-60 source capacity. For fixed-beam teletherapy.

ELDORADO G—50 r/m/m maximum cobalt-60 source capacity. Fixed-beam teletherapy unit.

CAESATRON (shown)—1300-curie caesium-137 source capacity. Fixed-beam technic.

• *See your G-E x-ray representative for complete details on equipment for x-ray and isotope therapy. Or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Room 1009.*

Dependable instrumentation is vital ***for thyroid function***

Evaluation of thyroid function with iodine-131* requires the dependable instruments which make up this newly designed, complete Nuclear-Chicago detection and measuring system. The DS5-1P Scintillation Detector, with its sensitive two-inch crystal and versatile collimator inserts, is ideal for regular uptakes, three dimensional depth studies, or pin-point collimation for scanning. The 132A Analyzer Computer is easy to operate, gives automatic percentage readout, and its internal spectrometer "tunes-in" only the selected and desired gamma radiation. A complete system, including the mobile stand, is surprisingly low in cost.

For thirteen years Nuclear-Chicago has been the leader in the development of high quality, reliable radioactivity instrumentation for the medical profession. We would be pleased to discuss your needs with you.

nuclear-chicago
CORPORATION
307 E. Howard Ave. • Des Plaines, Ill.

*"Diagnostic Application of Radioactive Isotopes" explains in detail the procedure for thyroid uptake study as well as eight other common radioisotope applications. Please ask us for your free copy.

udies with radioactive iodine
COMPLETE SYSTEM
WITH STAND
DS5-IP DETECTOR
132A ANALYZER COMPUTER

time it

for minimum exposure . . . maximum clarity

To date, no x-ray film has been produced that will entirely eliminate radiation exposure. But we have proven through innumerable tests that Gevaert world-renowned film may be subjected to a sharp reduction in exposure time and still produce a radiograph of finest definition. Gevaert's exceptional speed and wide latitude could be your answer to the exposure-conscious. Why not test it to prove our claim?

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KELEKET NINE INCH IMAGE INTENSIFICATION SYSTEMS

3,000

TIMES INTENSIFICATION

Power to See More Than Ever Before

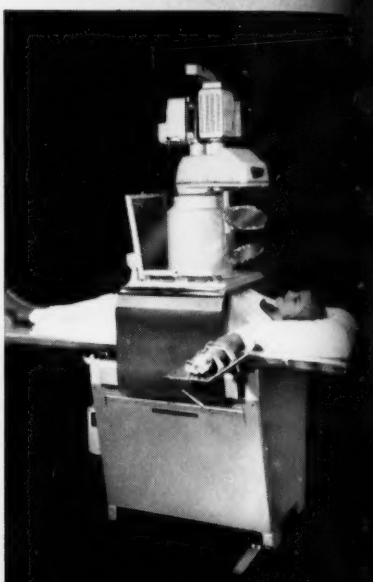
Now you can observe the entire adult heart and other large body organs more clearly and in greater detail than ever before. And, at the same time, cut radiation exposure 50 to 90% below that of conventional fluoroscopy.

The 3,000 times gain in Keleket nine inch image intensification systems is truly a new dimension in diagnostic x-ray. This greatly increased image brightness permits you to:

— use daylight vision in fluoroscopy yet retain a bright, sharp image at low radiation levels. Because you don't have to dark adapt, you eliminate wasted time in waiting — you can even read films between fluoroscopic examinations.

— for the first time, take crisp, high detail motion pictures within reasonable radiation levels. Three-thousandth-of-a-second exposures enable you to stop heart and blood motion. Body functions can be viewed quickly, slowed, stopped, seen frame by frame forward or reverse, and projected repeatedly for study. X-ray is not generated during film transport.

Keleket puts this new power in your hands in the form of highly practical systems.



Shown above is the new Keleket 9" Intensification System — with heart catheterization table. Note that the double direct viewing mirrors and the absence of screen tower permit simultaneous viewing by a second member of the heart team, even on the opposite side of the table.

ENGINEERED TO GIVE YOU A WIDE RANGE OF USE WITH AN UNUSUAL DEGREE OF MECHANICAL SIMPLICITY

— the image is viewed naturally, comfortably with *both* eyes.

— two can view the image at the same time, each with a separate mirror.

— you can view the image simultaneously during filming or TV so you can control what the cameras record.

— automatic brightness control maintains consistent image quality despite variations in the thickness or density of body parts under examination. "Auto-fast" control responds quickly as you scan the patient's body. "Auto-slow" control retains cyclical density changes as you study body functions. "Lock-in" feature freezes the brightness setting at the reference level and, with KV and MA constant, density changes such as the emptying of a bladder or the insertion of a dye, are shown as changes in brightness.

— The intensifier can be effortlessly "floated" up and out of the way when not in use freeing either the heart table or the regular radiograpic-fluoroscopic table for other examinations.

— The table, intensifier, control and accessories form a compact, integrated unit. Cassettes, spot filmer controls and the patient all remain within easy reach.

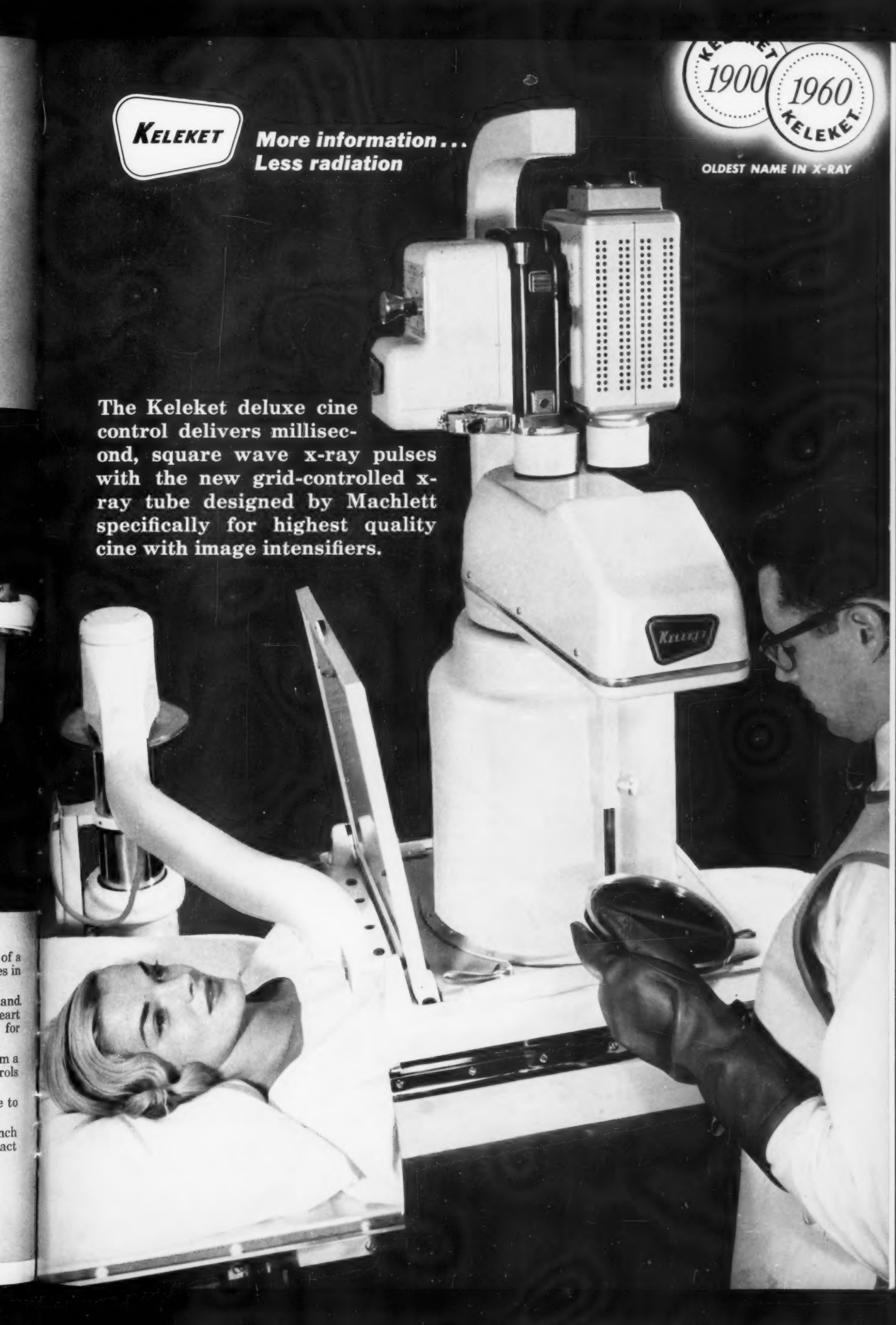
— Keleket intensifiers and cine units are adaptable to the quality equipment of most manufacturers.

For complete details and specifications on the Nine Inch Intensifier or the economical FIVE INCH model, contact your nearby Keleket representative or write

KELEKET X-RAY CORPORATION
1601 Trapelo Road, Waltham 54, Mass.
Representatives in all principal cities

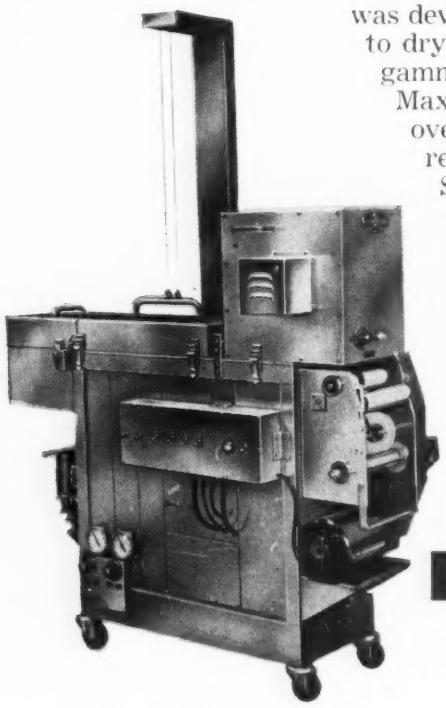
Tracerlab KELEKET

*Comparison of image on output phosphor with current Patterson CB-2 Screen


KELEKET
More information . . .
Less radiation
1900
1960
KELEKET
OLDEST NAME IN X-RAY
The Keleket deluxe cine control delivers millisecond, square wave x-ray pulses with the new grid-controlled x-ray tube designed by Machlett specifically for highest quality cine with image intensifiers.

maximum contrast retention

HIGH GAMMA AUTOMATIC ROLL FILM PROCESSOR



The PROCESSALL XR 6 - 12 roll film processor was developed expressly for complete, automatic, dry to dry processing of photosensitive films to the higher gamma desirable for cinefluorography.

Maximum contrast and identical characteristics result over every area of film to insure accurate, detailed reading.

Self threading, automatic temp. control, developing and fixing by submerged spray jets: washing by both water spray and air and by immersion.

Low tension scratch free operation. Requires 2' x 5' of floor space and minimal plumbing.

Once loaded, may be operated in normal room light.

Film capacity to 12" wide to 400 ft. long.

PROCESSALL

Detailed information on request.

OSCAR FISHER COMPANY, INC.
NEWBURGH, NEW YORK

DU PONT
REG. U. S. PAT. OFF.

X-RAY NEWS

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

No. 45

A SIMPLE AND INEXPENSIVE WAY TO ASSURE CONSISTENT RESULTS IN BARIUM EXAMINATIONS

By Jean E. Phillips, R.T., Sacramento, California

Beaker and hydrometer prove simple and effective way to measure specific gravity of barium solution.

Barium study typical of kind improved by this technique. ▶

About a year ago, we began to employ high-kilovoltage techniques in barium studies at the radiological laboratory of Drs. George L. Alexander and Robert Kirkpatrick. This was done in order to reduce patients' exposure to radiation and obtain radiographs of better diagnostic quality. At the same time, we decided to take an extra precaution. Because the barium solution used for these high Kv.P. studies is necessarily of lower viscosity, the need for solutions of consistent density became much more urgent. Therefore, we had to devise a way of accurately determining the specific gravity of our mixtures.

A local scientific supply house provided us with the answer: a simple hydrometer and a graduated

(*Continued on page 2*)

Have You an Article for "X-ray News"?

Perhaps you've discovered a new technique for making a particular kind of radiograph. It might be a different method of positioning your patient, or a special kind of examination you've found helpful. Or maybe you've come up with an entirely new device that helps you save time or money.

Well, whatever it is, we'd like to know about it (and so would our 34,000 readers). Any idea, technique or device that you feel might be of interest to your profession will be considered for publication. Just keep in mind these points:

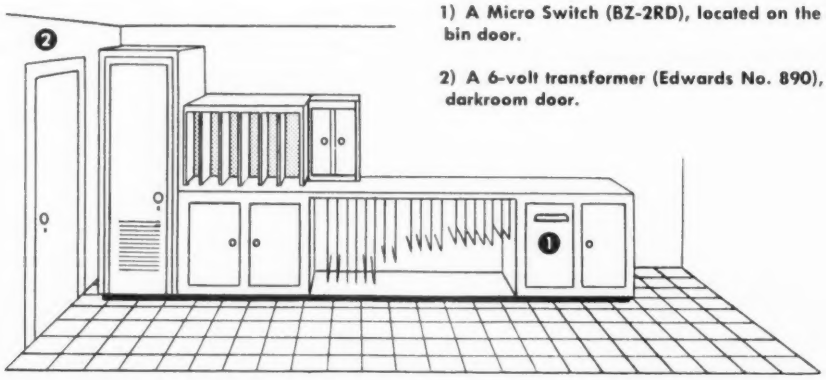
1) Submit your manuscript or outline any way you like, either typed or handwritten. All we ask is that you keep it *brief*—preferably not over 300-500 words.

2) If you possibly can, send along a radiograph to illustrate your story. Or, if it's not that kind of an article, try to include a photograph or two.

If you wish, your Du Pont Technical Representative will be glad to help you put your ideas down on paper or get the necessary photos. Any original material will be returned at your request. Just send your story, article or idea to:

Editor, **"X-ray News"**
E. I. du Pont de Nemours & Co. (Inc.)
Photo Products Department
Wilmington 98, Delaware

OVER ▶



1) A Micro Switch (BZ-2RD), located on the flange of the film bin door.

2) A 6-volt transformer (Edwards No. 890), placed above the darkroom door.

SIMPLE MICRO SWITCH SAFEGUARDS X-RAY FILM IN DARKROOM

The extreme sensitivity of x-ray film emulsions to white light fogging is a constant darkroom hazard. Here's a simple and economical method of insuring that film is not exposed accidentally (and wastefully) to ordinary white light.

Installed in an hour and a half, at a total cost for parts of less than $8.00, the system described here can be wired into any 110-volt circuit. Components are available at your local electrical supply house (see illustration).

The switch must be wired so that the contacts are normally closed. With this system in operation, there is little danger that x-ray film in the film bin will be ruined by accidental exposure to ordinary room lighting. As soon as the film bin door is opened, the Micro Switch automatically breaks the circuit and the lights go out.

(*Continued from page 1*)

beaker. Total investment: less than $5.00. Now, before we begin any radiographic examination of the digestive tract, we measure the specific gravity of the barium solution. How? Simply by pouring a small quantity of mix into the beaker and taking a reading with the hydrometer. This quick and efficient method assures us that the specific gravity of the solution remains at a constant 1:110. In order to maintain this standard, we've also arranged with our x-ray dealer to deliver *freshly mixed* barium to our laboratory every two weeks. As a result of these precautions, now routine in our office, the diagnostic quality of our radiographs is consistently high.

Tips for Technicians

Formations of algae, or slime, on the sides of the wash tank plague darkrooms throughout the country. Algae multiply in warm, stagnant water, and the use of warm tap water, plus the necessity of shutting off the flow of water overnight, provides ideal conditions for algae growth.

You can clean your wash tank completely and retard the growth of algae by treating them frequently with photographically neutral algecides. "Algex" tablets developed by the L. B. Russell Chemical Company, 1413 31st Avenue, Long Island City, New York, have proved a highly effective method of preventing and removing algae from wash tank walls.

During the periodic scrub-down of the processing compartment walls, the use of chlorox is recommended. Chlorox will remove the accumulated slime and rings from the sides of the tank.

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Photo Products Dept., Wilmington 98, Del.

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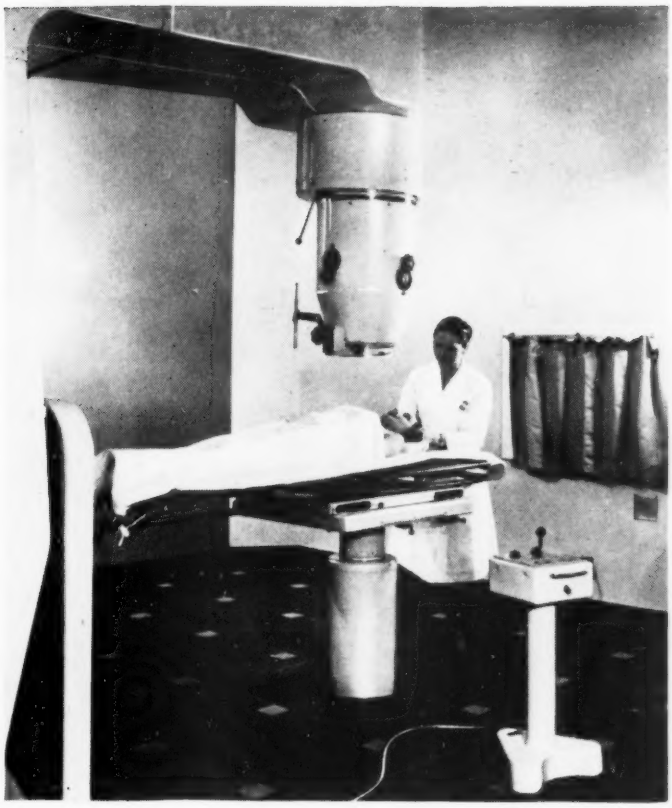
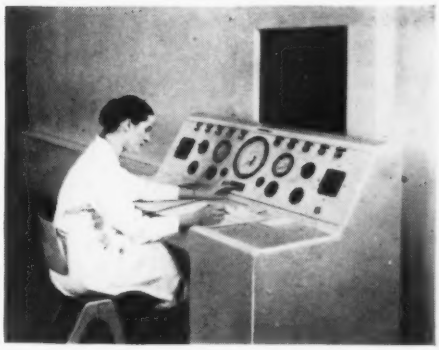


Patient positioning. The moveable control column to the right of the illustration controls the motorized drives for the angulation of the accelerator and the vertical movement of the couch.



All operating controls are located in this desk unit.

Speed up X-ray therapy with the

4-MeV ORTHOTRON

The 4-MeV Orthotron Linear Accelerator built by A.E.I. is already speeding up treatment in hospitals in different parts of the world. High x-ray output, speed in setting up patients and ease of control, mean that a single machine can bring the benefits of megavolt therapy to a large number of patients. For the busy x-ray therapy department the Orthotron is an essential major equipment, and a notable feature is its simplicity of control.

The first clinical linear accelerator in the world (operating at 8-MeV) was built by A.E.I. and has now been in operation in a London hospital since 1953.

NOTE THESE FEATURES

Filtered output up to 350 r/min with uniform field at 1 metre from the target.
Field sizes adjustable from 3 x 3 cm to 30 x 25 cm, within collimated field 31.5 cm diameter and 1 metre from target.
Accelerator moves in an arc round patient, distance between the x-ray target and centre of rotation being 1 metre.
Either skin entry point or tumour can be positioned at centre of the arc.
5 mm (collimated) spot size.
Design of diaphragm ensures small penumbra.

Please write for further details and a copy of our Research Series Booklet No. 33—
'Linear Accelerators in Clinical Service'

AEI

Instrumentation Division
Scientific Apparatus & X-ray Department
Associated Electrical Industries Limited
Trafford Park, Manchester 17

INTRAVENOUS CONTRAST MEDIA FOR VIRTUALLY EVERY UROGRAPHIC AND ANGIOGRAPHIC NEED...

RENOGRAFIN

Squibb Diatrizoate Methylglucamine

RENOGRAFIN 76%

for intravenous urography and angiography. Ampuls of 20 cc. and 1 cc. for sensitivity testing. Each cc. contains 760 mg. of diatrizoate methylglucamine.

RENOGRAFIN 60%

for intravenous urography and angiography. Ampuls of 25 cc. and 1 cc. for sensitivity testing. Each cc. contains 600 mg. of diatrizoate methylglucamine.

RENOGRAFIN 30%

for retrograde pyelography. Rubber-capped vials of 50 cc. Each cc. contains 299 mg. of diatrizoate methylglucamine.

NEW

RETROGRAFIN

Squibb Diatrizoate Methylglucamine and Neomycin Sulfate

FOR RETROGRADE PYELOGRAPHY WITH ADDED ANTIBACTERIAL PROTECTION...

Retrografin provides all the advantages of Renografin 30% and in addition, it contains 2½% neomycin (as sulfate) for widely effective bactericidal action in cases of proved or suspected urinary tract infection. Supplied in 50 cc. vials.

well tolerated systemically and locally...

"In view of the low incidence of reactions, we prefer Renografin to other opaques tested."
DeCarlo, J., and Sod, L.M.: Clinical Report to the Squibb Institute for Medical Research, March, 1956.

excellent visualization...

"...excellent opacification was obtained in a high percentage of the patients..."
Dennis, J.M.: Clinical Report to the Squibb Institute for Medical Research, March, 1956.

permits rapid completion of the urographic examination...

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Babaiantz, L., and Wieser, C.: Praxis 44:454 (May 19) 1955.

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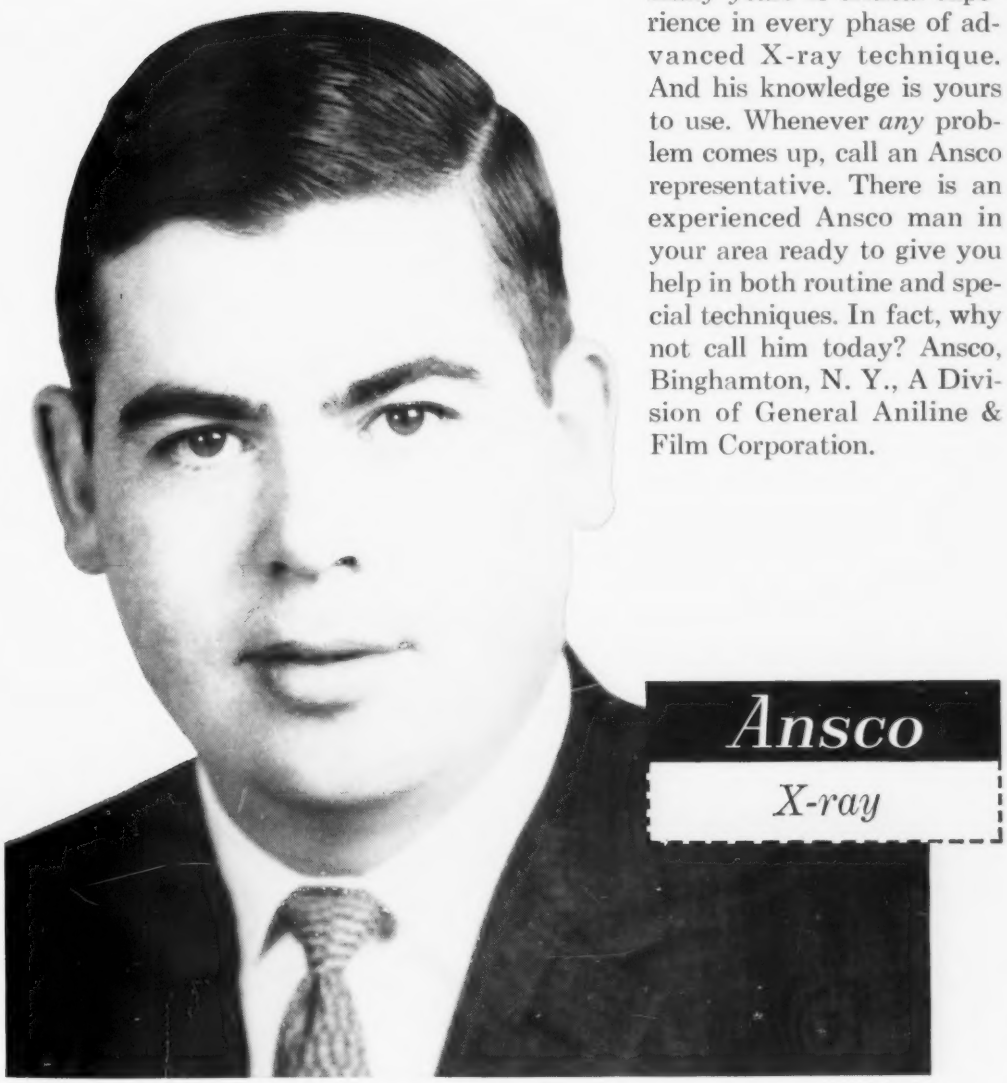

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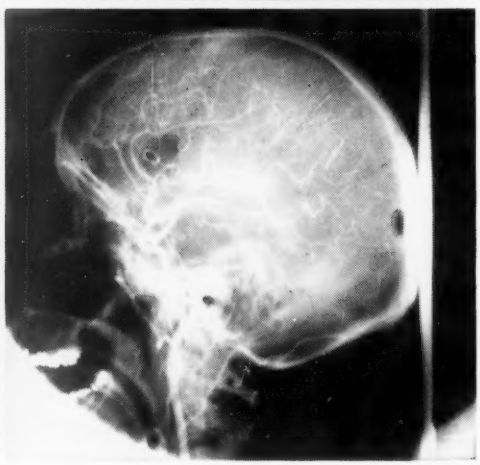

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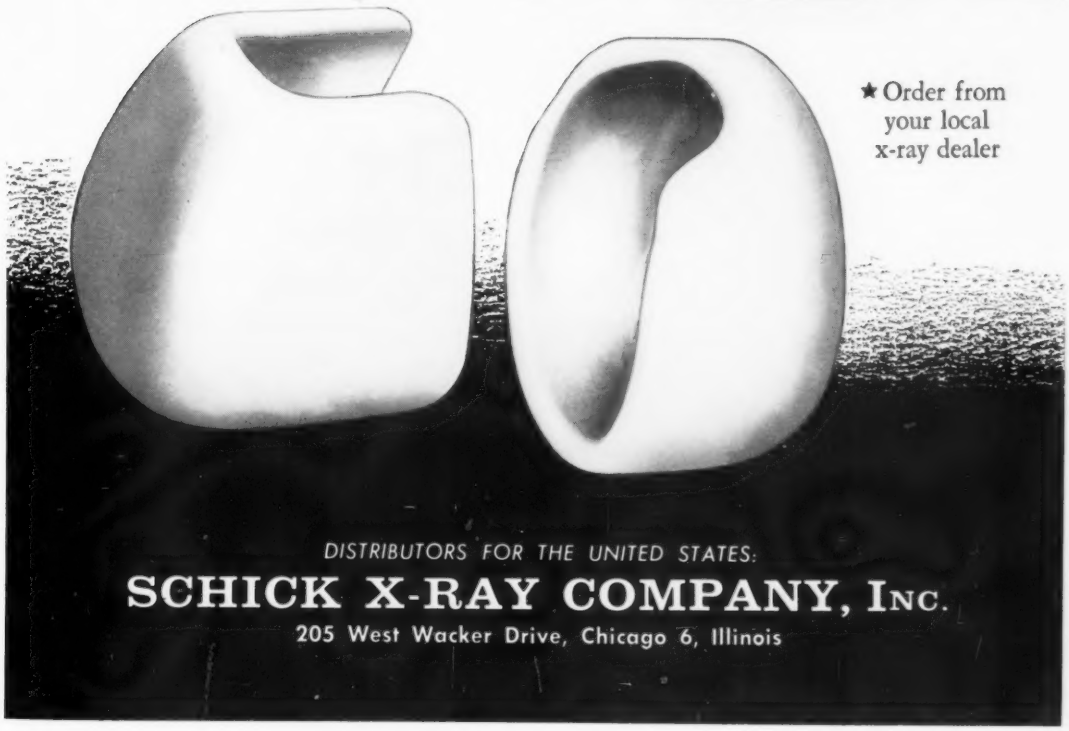

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Buckstein, Jacob (Cornell Univ.):
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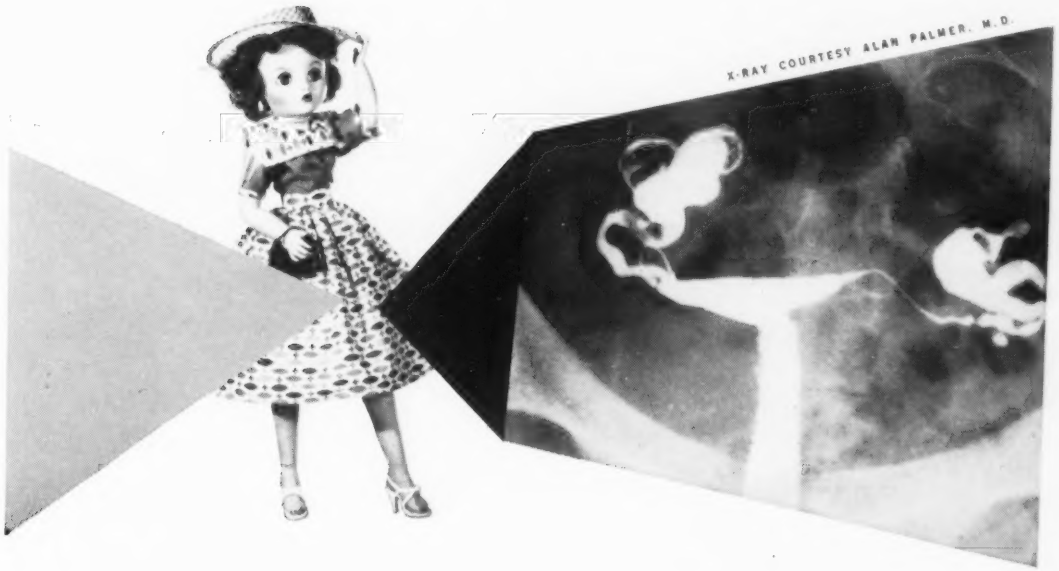

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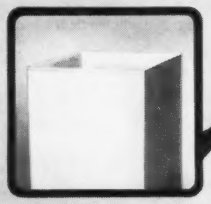

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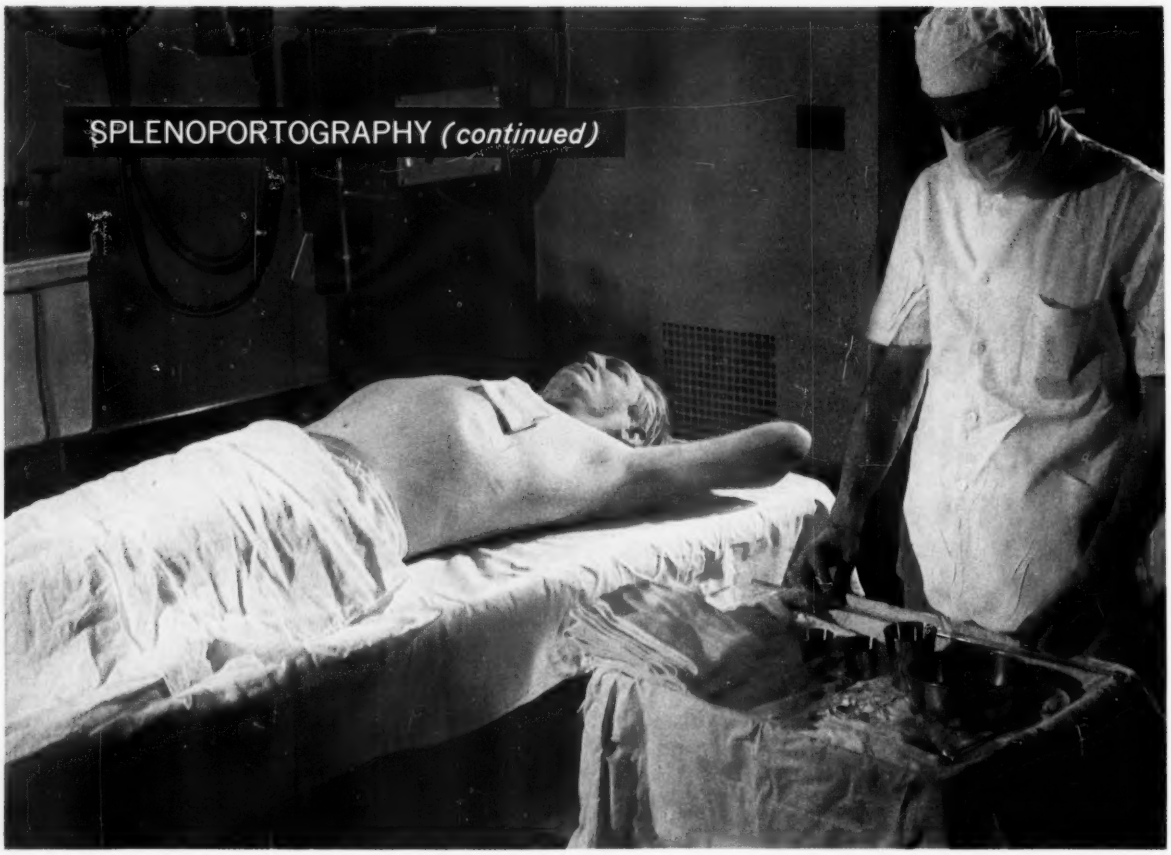

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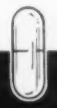

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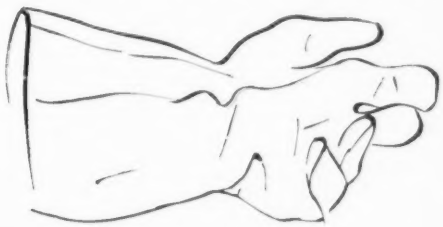

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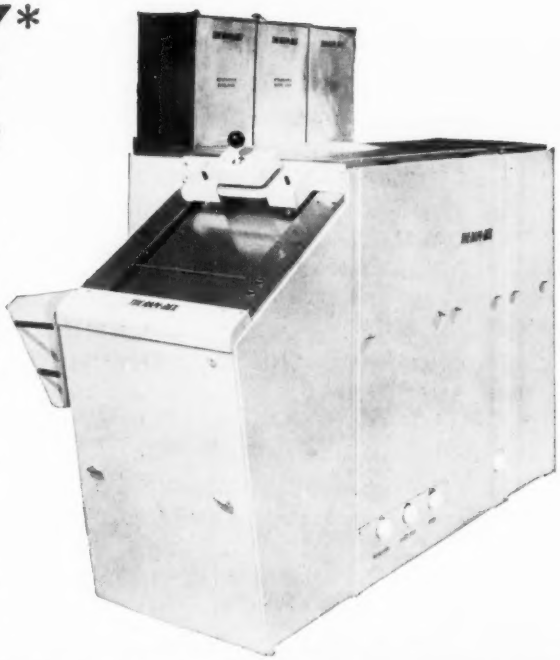

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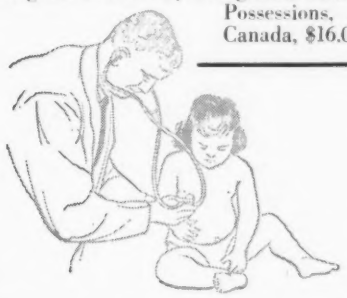

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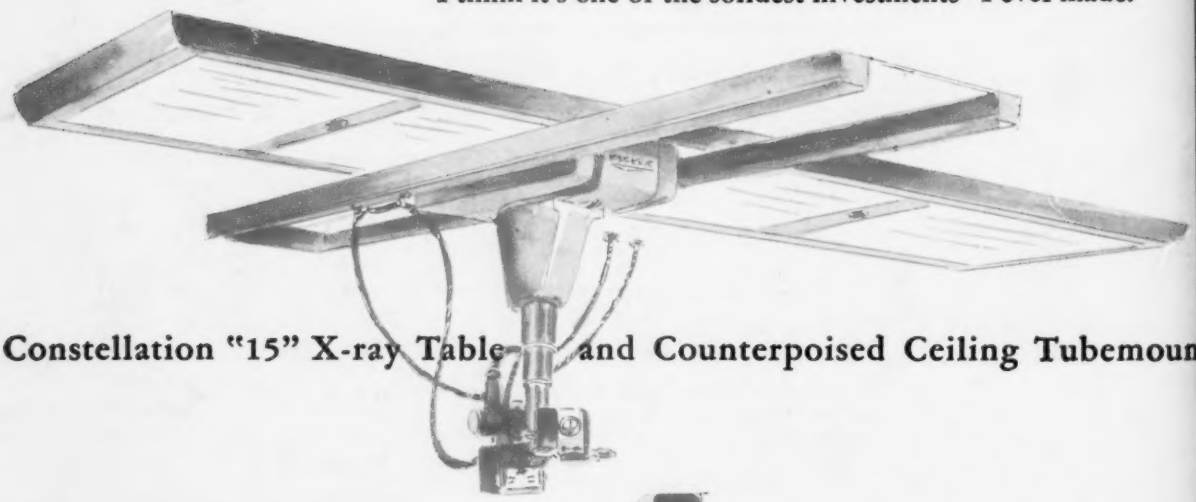

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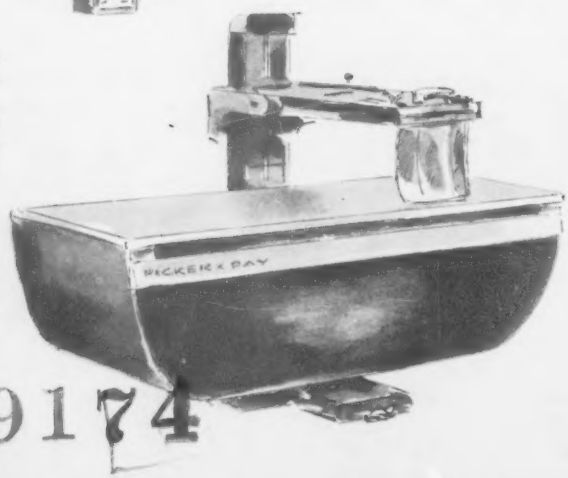

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